ECOPHYSIOLOGY OF THE EDIBLE OYSTER, *CRASSOSTREA MADRASENSIS* (PRESTON) FROM THE PULICAT LAKE, SOUTH INDIA

THESIS

SUBMITTED TO THE

UNIVERSITY OF MADRAS

FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

BY

R. THANGAVELU, M.Sc.,

DEPARTMENT OF ZOOLOGY

MADRAS CHRISTIAN COLLEGE

OCTOBER 1983

CONTENTS

P R E F A C E

There are several beds of the edible oyster, Crassostrea madrasensis (Preston) growing wild in most of the backwaters, creeks and estuarine regions along the east and west coasts of India, but strangely oysters are relished by a very few people nearby and therefore considerable quantities of oysters are allowed to perish without exploitation. There is an urgent and great need not only to enhance this protein-rich seafood production in India, but also to popularise it in view of the tremendous escalation of the Indian population.

Pulicat lake is the second largest brackishwater lake in India, and it is a major fishing centre for prawns, crabs and fishes. It has rich oyster beds from which oysters were collected since Hornell's times (1905-1922), and sold to Madras hoteliers, but now most of the oyster beds have become extinct due to some natural calamities such as drought and exposure in summer, and flow of monsoonal freshwater into the bed area, so that only the discarded shells are used by the local peasants for burning them into lime. Pulicat lake, which is only about 56 Km north of the Madras city, is shallow and unpolluted, and hence has a tremendous potential for seed oysters. The suitability

of the bottom of the Pulicat lake for oyster culture lies in the fact that the lake is shallow providing a flat, hard and sandy bottom for erecting culture racks. Further it might be possible to transport the oyster-seed by the country boats from one area to another, without any mortality, to carry out intensive as well as extensive culture operations. Above all, the Pulicat lake is an unpolluted lake free from any kind of pollutant, and it is rare to find a body of clean brackishwaters that provides for aquaculture operations today. Therefore, the present investigation is undertaken with the chief aim of collecting the field data concerning the distribution, feeding biology, reproductive biology, biochemical variations, ecology of settlement of the oyster-spat, possibilities of oyster culture, the food value and the effect of parasitism on oysters of the Pulicat lake.

Before taking up the present investigation on the feasibility of oyster culture on the Pulicat Lake, their biology and biochemistry, the author was engaged at the Central Marine Fisheries Research Institute, Tuticorin, on a project to evolve suitable farming techniques for large scale procurement of oyster-spat and for edible oyster culture. During 1978-79, a total of 8.82 lakhs of seed-oysters were collected at Tuticorin and supplied to the fisherfolk adopted by the Central Marine Fisheries

Research Institute, in their lab-to-land programme.

Until 1960, Pulicat lake was least explored scientifically, when a good motorable road from Madras to Pulicat Town was laid by the Government of Madras. Travel by country boats, the only means of transport, and camping at unhygienic fishing villages where even pure drinking water is not available, are some of the serious impediments to any research worker on this lake.

The establishment of the Estuarine Biological Laboratory in 1968, first of its kind on the lake, is a great venture and achievement of its Founder-Director, Dr. P.J. Sanjeeva Raj, Professor and Head of the Department of Zoology of the Madras Christian College. Several lines of investigations have been carried out since the establishment of the above laboratory on this resourceful lake. The present investigation, exclusively on oysters, is one in such a series.

The distribution pattern of the oysters in the Pulicat lake, information concerning the food and feeding of Crassostrea madrasensis so as to develop a culture of the required algae (diatoms) to supply the laboratory reared oysters, the most desirable method for the collection of oyster-spat and the best time of the year for the consumption of oysters based on their food value are also established in this study.

I am very grateful to Dr. P.J. Sanjeeva Raj for suggesting this problem for investigation, for guidance and suggestions right through and also for critically going through this manuscript. The present work has been supported by the award of a Senior Research Felloship to me by the Indian Council of Agricultural Research of the Government of India, to whom I am greatly indebted. I am also thankful to the authorities of the Madras Christian College for enabling me to make use of their laboratory facilities at Pulicat.

My special gratitude is to Dr. E.G. Silas, Director, Central Marine Fisheries Research Institute, Cochin, for his encouragement and also for the permission given to me to make use of the facilities available at the Research Centre of C.M.F.R.I, Madras. My sincere thanks to Mr.Nagappan Nayar, Officer-in-charge, Research Centre of C.M.F.R.I, Tuticorin, and to Mr. S. Mahadevan, Officer-in-charge, Regional Centre of the C.M.F.R.I, Mandapam, for their help and suggestions. I also wish to express my thanks to M/S M. Vijayakumaran, E.V.Radhakrishnan, R. Sarvesan and Mrs. Geetha Bharathan of the C.M.F.R.I, Madras for their help in several ways; and also to Mr. Virabhadra Rao, retired Senior Scientist of the C.M.F.R.I, for his helpful suggestions

To the members of my doctoral committee, Dr. E.R.B. Shanmugasundaram, Senior Professor, Department of Biochemistry, Alagappa Chettiyar College of Technology, Guindy, Madras, and to Dr. P. Govindarajalu, Professor and Head of the Department of Endocrinology, Institute of Basic Medical Sciences, Taramani, Madras, for their constant advice and also for the facilities extended by the latter for carrying out the biochemical estimations in his laboratory. I am very grateful and my special thanks are to Dr. R. Natarajan, Director, Centre of Advanced Study in Marine Biology, Porto Novo and to Mr. T. Tholasilingam, former Officer-in-charge of the C.M.F.R.I, Madras for enabling me to use their library facilities. I would like to express my sincere thanks to Dr. M.H. Ravindranath, Lecturer, Zoology Department, University of Madras and to his scholars for their timely help in the biochemical investigations. To my wife, Kalyani, I am grateful for her encouragement during the course of this investigation.

I express my profound thanks to all those who have sent me the reprints of their scientific publications. I would like to express my thanks to Mr. Arumugam and Mr. Ramadhass of Pulicat for their help in several ways.

LIST OF PLATES

LIST OF FIGURES

LIST OF TABLES

PLATE 1

Crassostrea madrasensis

A - External view

B - With right valve removed.

PLATE 1

A

B

As per the international rules of Zoological nomenclature given by Sacco (1897), the generic name Crassostrea is the first valid name for the oysters of the type angulata, virginica, gigas, madrasensis and cucullata etc.,. The distinguishing features of the genus Crassostrea are the very irregular shape of the shell, attachment to the substratum by the lower left valve, toothless hinge with linear margin, and hinge-ligament partly external and laminated upon a trigonal area in each valve. Besides these, there is only one adductor muscle viz., the posterior adductor muscle, the adult is oviparous, rectum does not pass through the ventricle, promyal chamber present and chalky deposits are lamellated. Preston (1916) gave a detailed account on the shell characters as follows:

Shell straight, irregular in shape, covered by numerous foliaceous laminae, left valve deep, right one slightly concave, hinge narrow and elongated, adductor scar sub-central, reniform and dark purple in colour, inner surface of valves white, glossy and smooth, purplish black colouration on the inner margin of the valves (Plate.1). Later, a brief account of the description of the soft parts of C. madrasensis has been given by Moses (1928).

DISTRIBUTION OF OYSTERS IN INDIA

Crassostrea madrasensis (Preston) is a predominant species of oyster in the estuaries and backwaters of Kerala, Karnataka, Tamil Nadu and Andhra Pradesh States in India (Plate.2). Hornell (1910) reported on the exploitation of C. madrasensis on the Pulicat lake and on the Ennore backwaters. In most of the areas, the oyster beds were destroyed by the shell gatherers for lime industry. Small scale exploitation of C. gryphoides is reported from the West Coast of India also from the States of Gujarat, Maharastra and Karnataka. The most important places where C. gryphoides is distributed and exploited are Satpati, Palghar, Navapur, Kalve on the Bombay coast, and Alibang, Jaytapur, Malwan, Karwar and Honavar, South of Bombay. C. cucullata (Born) inhabits mostly the rocky substratum on both the east and the west coasts. C. discoidea is distributed

PLATE 2

Map showing the distribution of edible oysters in India

aa - Crassostrea madrasensis

bb - C. gryphoides

cc - C. cucullata

dd - C. discoidea

hh - C. cristagalli

jj - C. folium

kk - C. cornucopia

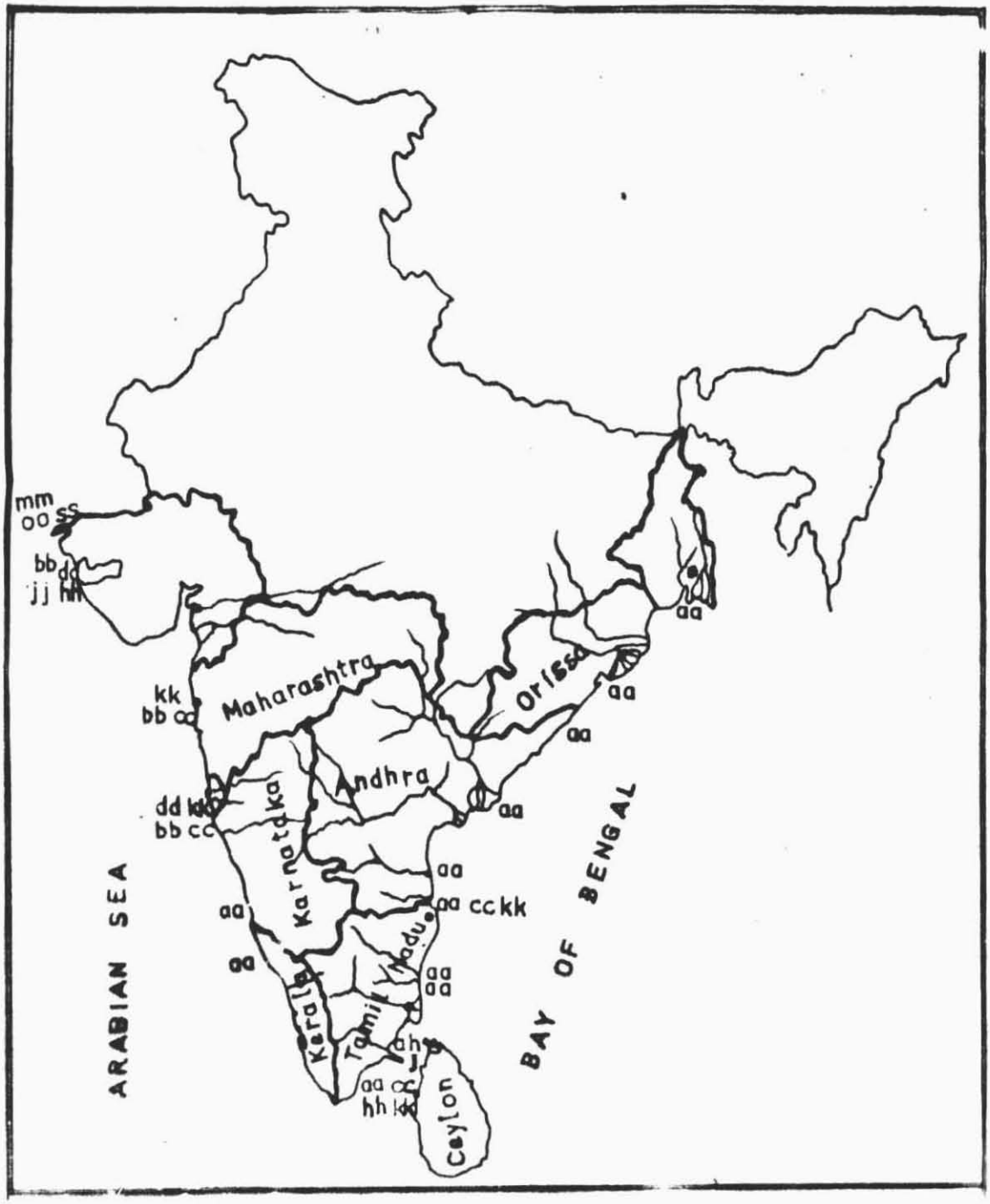
mm - C. glomerata

oo - C. belcheri

ss - C. quercina

PLATE 2

MAP SHOWING THE DISTRIBUTION OF EDIBLE OYSTERS IN INDIA



from North Kanara to Kutch. It is found in the Karachi and the Sind Creeks (Awati and Rai, 1931).

The following are the other species of oysters distributed in different parts of India but they are not commercially so important (Awati and Rai, 1931). C. cristagalli (Linnaeus) is found to occur on the Tanjore coast, Palk Bay, Gulf of Mannar in Tamil Nadu, and at Okha in Gujarat. Generally these oysters are found cemented to stones or Coral stones. C. folium (Gmelin) is found stray at Pamban in Tamil Nadu and in the Gulf of Kutch. C. cornucopia (Chemnitz) is generally found along with clusters of C. cucullata. The species has been recorded from rocks around Marmagoa in Karnataka. C. glomerata (Gould) are found on rocks around Karachi. Apart from the above, O. crenulifera Sowerby, O. bicolor Hanley and O. lacerata Hanley have also been reported from India. C. belcheri (Sowerby) and C. quercina (Sowerby) are found attached to shells of other oysters near Karachi.

HISTORY OF THE OYSTER CULTURE IN INDIA.

Hornell (1910) initiated oyster culture on the lines followed in Arcachon, France, and established an oyster farm on the Pulicat Lake. Unfortunately the culture programme was very much hampered due to some unknown reasons. Similarly some fishermen near the Bombay coast started the oyster culture by collecting the young oysters

and transferring them to some shallower regions (Rai, 1932). Later, the fishermen gave up this sort of culture, since the Government did not come forward to encourage them and also they were unable to improve their techniques. In the year 1975, the Central Marine Fisheries Research Institute took up oyster culture at Tuticorin, Tamil Nadu, for the utilization and augmentation of local resources and to impart the technical know-how of oyster culture to the interested private entrepreneurs. During the year 1978, the lab-to-land programme of the Indian Council of Agricultural Research was initiated to disseminate the transfer of technology to the fisherfolk. C.M.F.R.Institute adopted 15 families of fisherfolk at Tuticorin who were given this opportunity to take up this culture. This culture work is being carried out on a large scale at Tuticorin even now.

PREVIOUS WORK

Since oysters are highly nutritious, most aspects of their biology, growth, and ecology etc., have been studied by various earlier workers. Spawning of oysters has been reported by Hornell (1910a, 1922), Moses (1928), Panikkar and Aiyyar (1939), Paul (1942), Rao (1951), Rajapandian and Rajan (1980) and Stephen (1980). The early development of oyster has been partially studied by Moses (1928), Rao (1951a) and Devanesan and Chacko(1955).

Studies on the settlement of oyster-spat has been attempted by Hornell (1910b,c), Moses (1928), Devanesan and Chacko (1955), Nair (1975), Sundaram and Ramadhoss (1978), Rao and Nayar (1956),Reuben et al., (1980), Nayar and Mahadevan (1980), Thangavelu and Sundaram (1980), Purushan et al.,(1980), Dhulked and Ramamurthy (1980), Joseph and Joseph (1980) and Stephen (1980). Growth studies have been carried out by Hornell (1910), Paul (1942), and Rao and Nayar (1956). Some of the notable contributions to the food and feeding habits of oysters are those of Hornell (1908), Moses (1928), Devanesan and Chacko (1955) and Chacko (1954). Venkataraman and Chari (1951) and Stephen (1980) carried out the chemical composition and the food value of the oysters. Durve and Bal (1961) reported on the biochemical composition of the species Crassostrea gryphoides from the Bombay coast. But the nucleic acids of oysters have not been studied so far.

Earlier workers (Moses, 1928; Devanesan and Chacko, 1955) have reported on the food of the oyster and mentioned about the presence of various diatoms in the stomachs of oysters, but they have not attempted to study the feeding intensity in relation to the maturation of the gonad and the biochemical composition in the different body components of the oyster. In the present investigation biochemical aspects such as proteins, fats and carbohydrates have been studied in different body components of the oyster

to find out the exchange of nutrients between them. Study of the nucleic acids and inorganic phosphate in the different body components of the oysters, their seasonal variations in the different body components and also changes in relation to the different stages of maturation and food of the oyster, is a new field of work attempted in this thesis. On the basis of the spat settlement, the feasibility of oyster culture on the Pulicat Lake is discussed in detail. The infection of the oysters by the trematode parasite Bucephalopsis haemeana in the various size-groups of oysters, seasonal infection, gonadial changes and effect of low salinity on the infection have also been attempted in this thesis.

TOPOGRAPHY OF THE PULICAT LAKE

The topography of the Pulicat Lake has been described in detail by Russel (1898), Hornell (1910), Chacko et al. (1953), Krishnamurthy and Rao (1970), Joel (1973) and Paulraj (1976).

Pulicat Lake (Plate 3), located between the 13°26' and 13°43'N. latitudes and between the 80°03' and 80°18'E. longitudes, is the second largest brackishwater lake or lagoon in India, lying almost parallel to the Bay of Bengal and is covering an area of 461 sq. kilometres

PLATE 3

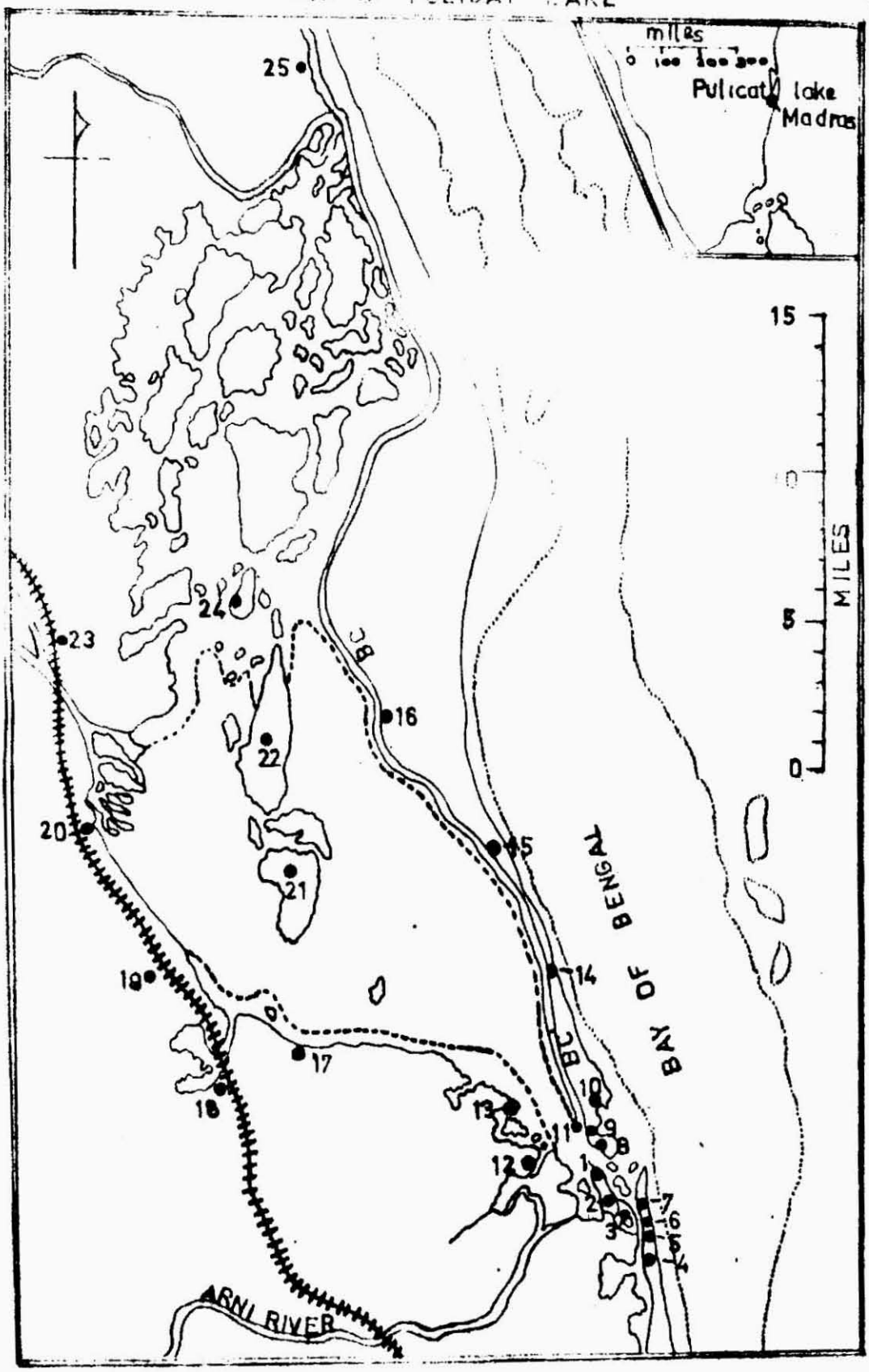
MAP OF PULICAT LAKE.

1. Kottaikuppam
2. Pulicat
3. Edamani
4. Koraikuppam
5. Sattankuppam
6. Lighthouse kuppam
7. Gunakuppam
8. Karimanal
9. Dhonirevu
10. Moosamani lock
11. Sambasapallikuppam
12. Avirivakkam
13. Annamalaicherry
14. Arangam
15. Pulincherry
16. Zonigapalem
17. Sunnambukulam
18. Elavur
19. Arambakkam
20. Tada
21. Irakkam
22. Veynad
23. Sulurpet
24. Atakinitippa
25. Dugirajapattinam

BC. Buckingham Canal.

PLATE 3

MAP OF PULICAT LAKE



between the Chingleput District of the Tamil Nadu State and the Nellore District of the Andhra Pradesh.

The lake is about 59 kilometres north to south, and the maximum width from east to west, in the northern sector, is about 19 kilometres. The narrowest region of the lake is between Dhonirevu and Monaikal, measuring about 350 metres. The average depth of the lake is about 1.5 metres and the maximum depth is about 7.0 metres.

The lake, at its southern end close to the Pulicat Town, opens into the Bay of Bengal by a narrow pass(mouth), about the width of 200 metres. From March till September, the pass gets completely closed, once in about five years or even a little more frequently, if there is no monsoon flood in any particular year.

In the northern part of the lake, there are two larger islands, Veynad and Irakkam, and a much smaller one called Kuruvithittu, all of which have a tremendous potential for the deposits of sub-fossilised clam shells. On the easternside, the Sriharikota Island extends north to south all along, as a narrow strip of sand between the lake and the Bay of Bengal.

The total area of drainage of this lake is about 440 sq. kilometres (Russel, 1898). The Buckingham canal and the Silanhurti River (a branch of the Arni River), in the southern sector of the lake, and the rivers

Kalangi and Swarnamuki in the northern sector, bring in enormous quantity of flood waters, and consequently the average water level increases by about 1.5 metres during the monsoon season. The mud-flats around Pulicat, Annamalaicherry, Arangam, north of Tada, north-east of Veynad and the low-lying areas adjoining the Buckingham canal in the south, all get flooded during the monsoon period, but towards the summer and post summer months, from March to September, the water recedes slowly and the water level falls by about 1.2 to 1.5 metres from the mean sea level.

DEPTH

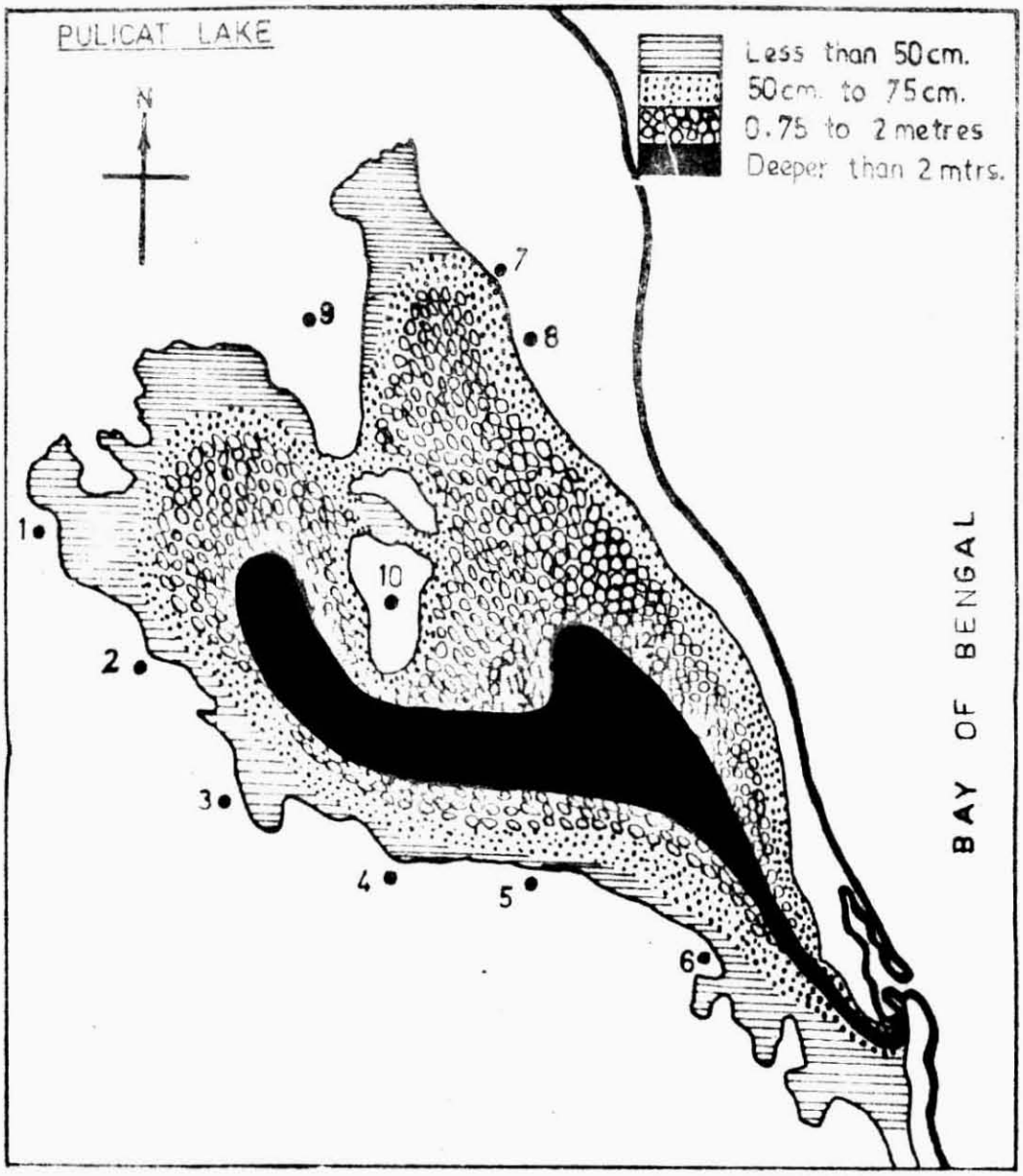
The maximum depth of the lake is near Theevu (Plate) measuring about 7 metres, whereas the mean depth of the lake is only about 1.5 metres. The lake is divided into four regions according to the depth of the water. The portions deeper than 2 metres form the first category, and they extend northward like a narrow canal from the pass, upto Vallimonai and then westwards touching the southern and western portions of Kuruvithittu. The northern portion of this first category, is located between the village Poondikuppam and the southern tip of Venad. The second region, less than 2 metres deep but above 0.75 metre, surrounds the first region upto the eastern shore of the main part of the lake. Thirdly, the shallow areas covering the vast expanses of the lake, ranging between 0.5 metres and 0.75 metres deep are located

PLATE 4

Map showing the four regions of Pulicat Lake according to depth.

1. Tada
2. Poondi
3. Arambakkam
4. Sunnambukulam
5. Mongod
6. Annamalaicherry
7. Zonigapalem
8. Pulincherry
9. Veynad
10. Irakkam
11. Kuruvithittu
12. Vallimonai

PLATE 4


PULICAT LAKE
N
Less than 50cm.
50cm. to 75cm.
0.75 to 2 metres
Deeper than 2 mtrs.
1
2
3
4
5
6
7
8
9
10
BAY OF BENGAL

north of Tada, the north-east of Venad, the marginal area lying between Sunnambukulam and Pulicat, the Mangod and Annamalaichery Paraval (shallow area), and across the Buckingham canal, south of Kottakuppam lock. Lastly, the fourth region upto a depth of about 0.5 metres, usually representing the monsoon overflow, is encountered at the northern extremity of the lake and also southwest and west of the Pulicat Town. The latter region approximately covers 30 percent of the total area of the lake. Flood waters from October to January, inundate vast areas adjoining the lake, and the horizontal extent so covered, depends on the gradient or the slope of the area in question. During the monsoon period, the horizontal intertidal distance is about 2 to 3 metres. Apart from this, prevailing winds exert great influence in carrying the water away, thereby exposing or covering more area on the shore and the shallower regions adjoining the lake. Normally the lake provides a typical lagoon-like environment. However due to severe drought during the months of June, July, August and September, the temperature and salinity increase rapidly. Consequently, this has a drastic influence on the flora and fauna of the lake, which is dealt with in a later chapter.

TIDES

Due to the effect of tidal flow, a difference of about 1.0 metre in the height of the water column is

encountered at the pass, at the peak of the spring tides, and the tidal influence is felt upto Vallimonai, located roughly at a distance of about 10 kilometres north of the pass. The tidal amplitude decreases as the sand bar closes up the pass during the post monsoon months.

NATURE OF THE BOTTOM

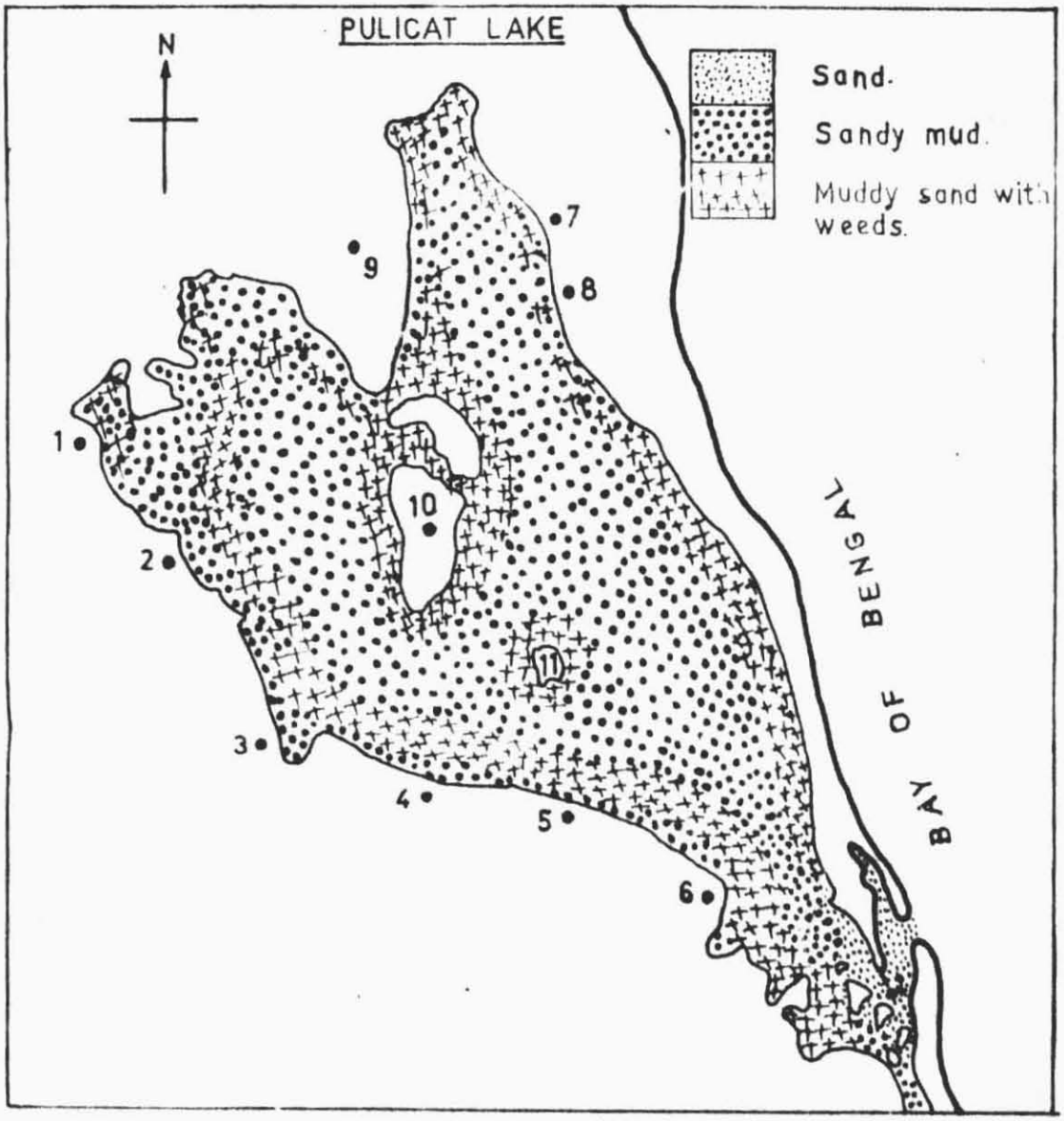
Hornell (1910) observed fine quartz sandy bottom along the shores of the lake, soft and oozy bottom at regions closer to the pass and oozy mud bottom at deeper regions and at the northern portions of the lake. Krishnamurthy(1971) observed three types of substrata in the Pulicat lake (Plate 5). A zone characterised by the predominance of sand in the substratum with little admixture of mud, a second zone having sand and mud in equal proportions with patches of weeds, and a third zone consisting of entirely of mud. The sandy bottom extends from the pass upto the Moosamani lock, and northwards along the eastern shore of the lake, including the shallow Karimanal inlet area. On the western side of Irakkam, the substratum is of the sandy-mud type with large amounts of sub-fossilised clam shells. The restriction of the sandy bottom to the area near the pass, may be due to the prevailing strong current, which churns the bottom and carries away the silt and mud.

PLATE 5

Nature of the bottom of the Pulicat Lake.

1. Tada
2. Poondi
3. Arambakkam
4. Sunnambukulam
5. Mongod
6. Annamalaicherry
7. Zonigępalem
8. Pulincherry
9. Veynad
10. Irakkam
11. Kuruvithittu
12. Vallimonai

PLATE 5



In the peripheral areas of zones II, III and IV (Plate 6) the bottom is of the muddy-sand type with weeds. In the shallow areas of the zones V and VI, patches of weeds are observed where the bottom is of the muddy-sand type. The eel grass, Enhalus koenjii and Halophila ovalis are the two common weeds found all over the lake. At the southernmost part of the lake, near Dhonirevu region, seagrass Diplanthera uninerves, brown algae Rosenvingea intricata, Lyngbya, Phormidium and green algae Enteromorpha sp. and Chaetomorpha sp are conspicuous. At the Annamalaichery area, the number of algae was found to be more and were constituted by Enteromorpha compressa, Lyngbya sp., Phormidium sp., Hypnea valentiae, Chaetomorpha sp., Halophila ovalis, Gracilaria verrucosa, Rosenvingea intricata and Diplanthera uninerves. At certain places like the eastern part of Irakkam, Idakalmonai, Kottamonai, Nagamonai, Acetabularia and Oscillatoria spp. form the bulk of the weed-bed.

In the deeper regions, except in the neighbourhood of the Pulicat bar, the bottom is of a sandy-mud type, with silt and clay as the major components and is extremely soft and dark grey in colour.

HYDROLOGICAL PARAMETERS

Hornell (1910), Chacko et al. (1953), Srinivasan and Pillay (1972) and Kaliyamurthy (1973) have given brief accounts on the hydrography of the Pulicat lake. The unique

PLATE 6

Zonation of the Pulicat Lake

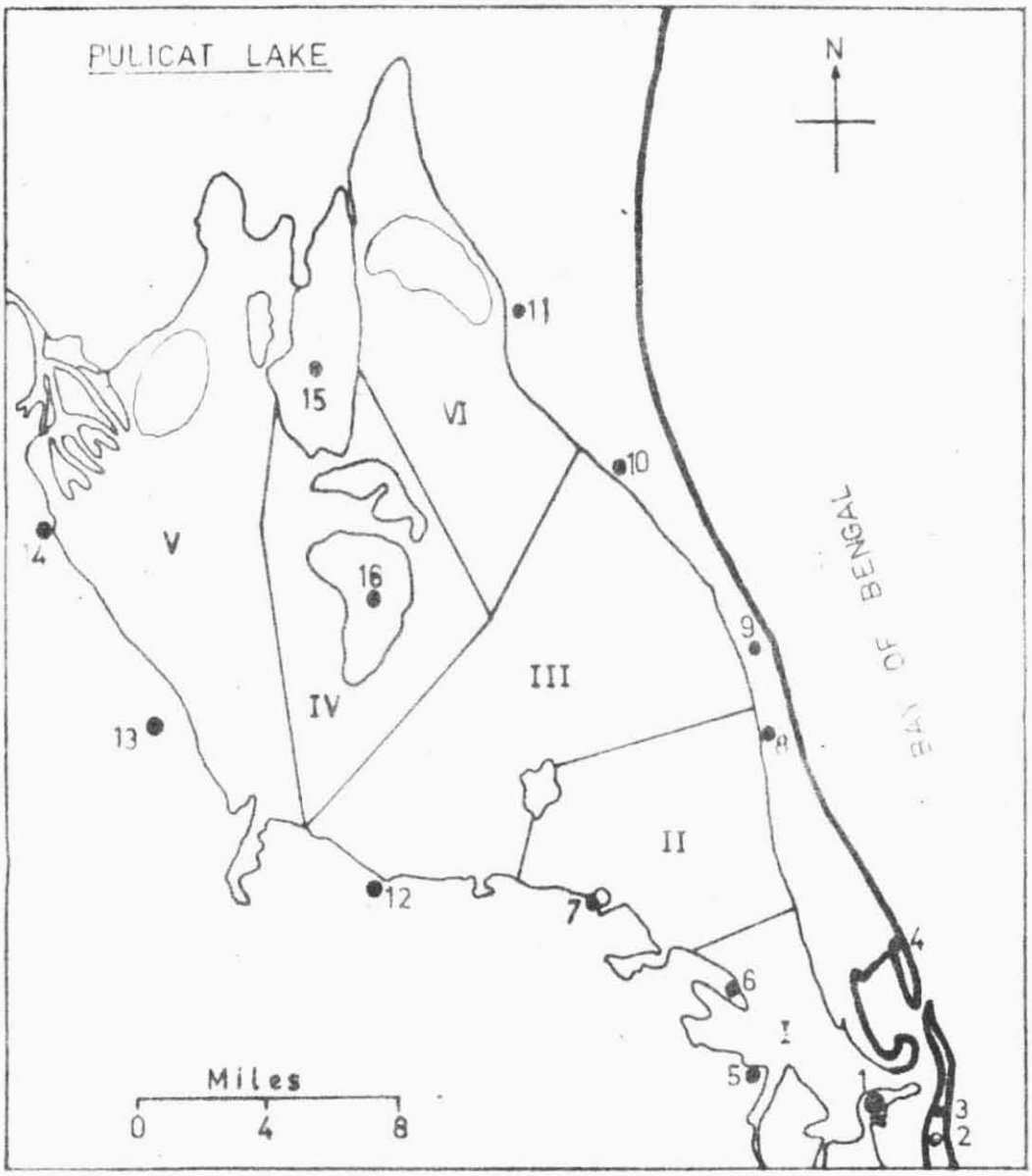
1. Pulicat
2. Sattankuppam
3. Lighthousekuppam
4. Sambasapallikuppam
5. Avirivakkam
6. Annamalaicherry
7. Mongod
8. Thanneerpandal
9. Arangam
10. Pulincherry
11. Zonigapalem
12. Sunnambukulam
13. Arambakkam
14. Tada
15. Veynad
16. Irakkam
17. Kuruvithittu

I, II, III, IV, V, VI - Different zones

I, II, III - Southern region

IV, V, VI - Northern region

PLATE 6


PULICAT LAKE
N
BAY OF BENGAL
I
II
III
IV
V
VI
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Miles
0
4
8

feature of the lake is that during the flood season in December, the salinity is extremely low, but during the summer and post summer months (April to September), it is hypersaline. Hydrological conditions of the lake are influenced by the following factors: 1. The North East Monsoon, which is active during the months of October, November and December and hence the influx of freshwater from the rivers and from the Buckingham canal, 2. the closure of the pass and the consequent stagnation and evaporation of the lake water, during the post-summer months, 3. the high atmospheric temperature in summer which results in the heating of the shallower waters, and 4. the direction and speed of the prevailing winds. Based on the above hydrological and meterological factors, the following four seasons are recognised.

Summer (April-June): During this period the atmospheric temperature increases rapidly resulting in high temperatures of the lake water, especially in the shallower northern sector. Due to the poor inflow of freshwater the salinity increases in all the zones, and is particularly most pronounced in the northern sector. Due to high temperature, high salinity and insufficient mixing of water, fishes and prawns moves to the deeper regions of the lake where the bottom temperature is comparatively low. This is evident from the high catches of prawns and fishes in the deeper southern sector, and the low catches in the northern shallower sector.

Post-Summer (July-September): During the post-summer months, there is a gradual decrease in temperature of the water, due to the summer and post-summer rains, whereas the salinity is on the increase, as this rainfall does not necessarily bring in freshwater into the lake through the rivers. Because of the hypersaline conditions and equally high temperature, which perhaps prevent the colonization of the animals, these parameters greatly influence the distribution of the larvae of prawns and fishes.

Monsoon (October-December): Due to the prevailing North East Monsoon rains and the consequent high influx of freshwater from the rivers, the Buckingham canal and the other freshwater drainage channels, the temperature and the salinity decreases enormously in both the sectors. The inflowing freshwaters break open the sand-bar, and the tidal circulation is restored. As a result, salinity at the surface is very low(4-8‰) but the bottom salinity is almost equal to that of the sea water (32‰-34‰). The same phenomenon was observed in the lake by Joel (1973). The influx of freshwater in the lake increases the turbidity of the water, since there waters bring in enormous quantity of suspended silt and detritus. During this season, the juvenile and sub-adult prawns are observed to move to to the deeper regions of the southern sector and then emigrate into the Bay of Bengal.

Post-Monsoon (January-March): This appears to be the most favourable season for the fauna and flora of the lake in general, and for the survival and growth of the post-larvae, juveniles and sub-adults of the penaeid prawns and of fishes. Colonization of the bottom by the animal and plant communities is intense during this season.

Some preliminary observations on the benthic fauna of this lake were made by Krishnamurthy (1971), followed by a detailed study of the seasonal abundance and distribution of the fauna by Ramamohana Rao (1974) and of the flora by Radhakrishnan (1973). A study of the important hydrological parameters along with the plankton, benthic flora and fauna of the whole lake during the pre-monsoon, monsoon and post-monsoon periods is attempted here, based on the data collected between June '72 and May '73 by Raman et al.,(1975).

Of the three zones, the southern zone is found to be the most productive (average 1410/m^2) followed by the middle average (1384/m^2) and northern(average 1115/m^2) zones as given by Raman et al., (1975). Molluscs and polychaetes were responsible for the maximum production in the southern zone whereas in the middle zone amphipods, molluscs and polychaetes formed the important groups in the order of abundance. In the northern zones also amphipods are recorded in maximum quantities followed by molluscs and tanaids.

The lake is highly productive, with an annual production of 312/$g^C/m^2/Yr$ (Kaliyamurthy, 1973). It is estimated that 0.01 percent of the primary production alone is harvested in the form of fish and crustaceans from the lake (Kaliyamurthy, 1973).

Plankton concentration is generally high during the post-monsoon, with a preponderance of zoo-plankters. The macro-vegetation in the lake consists of rooted submerged plants such as Halophila ovalis and Cymodocea isoctufolia. The highest density (3250 nos/m^2) is recorded from the east coast of this lake, and the lowest (37 nos/m^2) from the south west. The perphyton of the macrophytes consists mostly of diatoms varying from 5 to 2455/m^2. Bottom fauna consists mostly of polychaetes, tanaids, amphipods and molluscs. Their concentration was more during the monsoon and post-monsoon seasons, the pre-monsoon season showing the lowest number. Based on the benthic productivity, the lake can be classified as mesotrophic.

DISTRIBUTION OF C. MADRASENSIS IN THE PULICAT LAKE-HABITAT

The distribution of the oysters in the Pulicat lake is illustrated in Plate 7. Extensive oyster beds as shown in Plate 8 are usually found to occur in the southernmost region of the lake. There is a rich oyster bed found near the Karimanal inlet. Oysters are found sparsely scattered and grown wild near the pass of the lake.

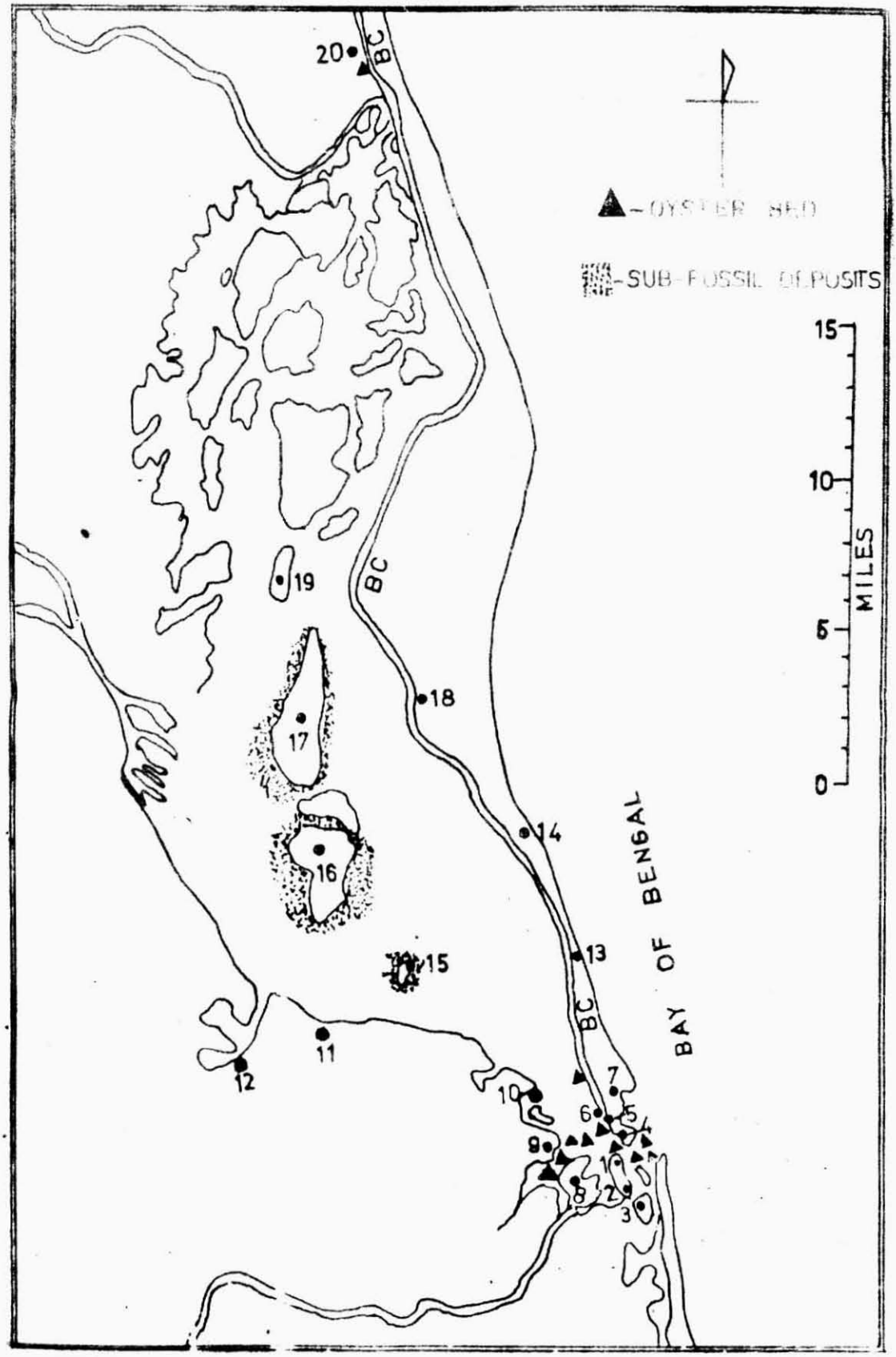
P L A T E 37

Map of the Pulicat Lake showing the distribution of oysters and sub-fossil deposits.

1. Kottaikuppam
2. Pulicat
3. Edamani
4. Karimanal
5. Dhonirevu
6. Sambasapallikuppam
7. Moosamani lock
8. Kulathumedu
9. Avirivakkam
10. Annamalaicherry
11. Sunnambukulam
12. Elavur
13. Arangam
14. Pulincherry
15. Kurivithittu
16. Irakkam
17. Veynad
18. Zonigapalem
19. Atakinitippa
20. Dugirajapatnam.

PLATE 7

MAP OF PULICAT LAKE SHOWING THE DISTRIBUTION OF OYSTERS AND SUB-FOSSIL DEPOSITS



A triangular portion of the weed-infested land, exposed during the low tides, between Kottakuppam and Gunakuppam and the northern-most region, there are four oyster beds each extending to about 10 to 16 sq.metres. The North western side of Pulicat or Kulathumedu area, where there is an extension of the lake towards the south west, is characterised by the presence of an extensive oyster-bed, which is extending in patches to about a half kilometre (Plate 8). It is called the Sinna paraval bed, as also mentioned by Hornell (1908). The oyster-bed area is muddy sand, devoid of weeds. The bed is completely exposed during the low tide and is submerged during the high tide. On either side of the bed when there is a high tide there are streams of water which carry the food organisms. The oysters in this bed occur in clusters readily separable into individuals. They are long and narrow, sub-spatulate in form and are of remarkably uniform growth pattern. The cluster is characterised by the presence of crowded oysters at the centre. Large number of discarded shells of the past oyster beds can be found at the westernside of the present bed.

There appears to be a natural oyster-bed on the rocks at the lock area, and also nearby the lock, in the muddy area of Buckingham Canal near Kottakuppam. Oyster-beds are also found to occur in small patches on the

PLATE 8

View of the oyster bed in the Pulicat Lake.

northern side of Dhonirevu and also near the Moosamani Lock area, where the bottom is sandy-mud, devoid of weeds. In between Atakinitippa and Arangam, no live oysters can be noticed anytime. However, oysters are found to occur near the Buckingham canal of the Sriharikota island and at Kondurpalayam where there is another pass (mouth), at the northern end of the lake.

CHAPTER ONE

FOOD AND FEEDING

Some of the notable contributions to our information on the food and feeding habits of Crassostrea madrasensis are those of Hornell (1908), Moses (1928) and Devanesan and Chacko (1955); of Ostrea edulis by Orton (1927b); of Crassostrea virginica by Jorgenson (1952), Jorgenson and Goldberg (1953), Loosanoff (1949, '65, '71), Davis (1953) Davis and Guillard (1958), Walne (1958) and Galtsoff (1964), and of Crassostrea gryphoides (Schlothein) by Durve (1964b).

Despite the fact that several workers have attempted to study the food and feeding habits of oysters, there has not been any attempt to study in detail 1) the food preference of oysters in waters like those of the Pulicat lake where the environmental parameters are different, 2) their feeding in relation to the availability of food in the environment, 3) the seasonal variations in the intensity of feeding and 4) their feeding in relation to their reproductive status.

MATERIAL AND METHODS

The natural oyster-beds in the Pulicat lake were visited once a fortnight, and the oysters were removed from the clusters by means of a hammer, one by one at random. The epifauna and epiflora of the oysters were removed by using a scrapper and a fibre brush. The oysters were taken to the laboratory and preserved in 5% formalin, for using the same in subsequent studies. The salinity ahd temperature of the oyster-bed also were recorded regularly.

After taking the morphometric measurements, the oysters were shucked and the shells were removed. The condition of the gonad was noted by the Smear Method, under a microscope. A narrow-mouthed pippette was slowly introduced through the mouth till it reached the stomach and the gut contents were thus pipptted out and placed on the plankton counting chamber. This was repeated for a minimum of five times to remove all the contents of the gut completely. 'Points' were alloted(i.e., 100, 75, 50, 25, 10) for the quantity of matter removed from the gut of oyster. The contents of the gut were spread well on the plankton counting chamber and the number of diatoms were counted. All detritus and unidentifiable algal matter were grouped together and were expressed separately in percentages.

Unlike in the fishes, the quantity of food consumed by oysters is very little which makes it difficult to

determine the actual volume by the Displacement Method. Therefore, the 'Points Method' (Hynes, 1950) was employed in the present study. The final analysis of the food of C. madrasensis was made by employing the method of 'Index of Preponderance', of Natarajan and Jhingran (1961). The percentage of occurrence of the difference items of food, and the percentage of numbers in different months of the year were determined by summing the total number of occurrences of each item was calculated. The index of preponderance is given by the formula

$$Ii = \frac{V_i \, O_i}{\sum V_i \, O_i} \times 100$$

Where 'V' and 'O' represent percentage of volume and occurrence respectively. In the case of the oyster, instead of volume, numbers were taken into consideration.

Quantitative samples of plankton also were collected from the oyster-bed area, by filtering 200 litres of water through a hand net made of 20 # bolting silk. The collected material was preserved in 2 percent formalin and kept in plankton bottles separately.

The plankton concentrate preserved in formalin was made upto 100 ml in a measuring cylinder. After thoroughly mixing the contents, 1 ml of it was transferred to the plankton counting chamber and the various phyto-and zooplankters were identified upto the generic

level and counted under a compound microscope. The same was repeated five times and the average was taken into consideration and expressed as numbers/100 lites of water.

RESULTS

SEASONAL ABUNDANCE OF THE PLANKTONIC ORGANISMS IN THE ENVIRONMENT.

This study was conducted for two years, from July 1980 to June 1982. Many of the diatoms in the plankton appear to be seasonal. But species of Navicula, Nitzschia, Coscinodiscus, Rhizosolenia, Pleurosigma were found abundant throughout the period of observation, each with its own seasonal fluctuations (Table 1). A higher percentage of Navicula was found in September and February in both the years, but in all the other months they were found at a moderate level. The percentage of Nitzschia was high during the month of June in both the years. However, in September '81, the percentage was maximum whereas in September of the previous year it was very low in percentage. In general, high incidence of Nitzschia was found between June and September. The fluctuations of Coscinodiscus were very little. There were more than one peak of Coscinodiscus in the plankton. The maximum peak was found in July '80 but the other peaks also were observed in October, December, February and June. Thus Coscinodiscus shows fluctuations right through the year.

TABLE 1

Monthly variations in the percentage of diatoms of the Pulicat Lake.

Diatoms	Month and Year																							
	July 1980	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 1981	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 1982	Feb.	Mar.	Apr.	May	June
Navicula	13.21	11.59	17.39	13.04	13.90	15.79	15.52	18.52	18.45	5.56	6.30	10.67	16.39	9.30	13.89	12.50	9.52	10.11	16.72	23.53	5.21	1.11	5.45	11.28
Nitzschia	13.21	11.59	7.25	5.80	13.90	8.77	6.89	7.41	8.42	8.97	11.8	22.67	3.15	37.21	50.00	28.13	33.33	15.73	13.38	29.41	12.50	8.85	14.71	31.00
Coscinodiscus	26.41	13.04	17.39	23.20	8.22	21.05	10.34	11.11	9.47	16.24	11.81	4.67	14.75	16.28	13.89	21.88	14.29	14.61	10.03	17.65	12.50	10.72	8.53	16.91
Rhizosolenia	13.21	5.80	4.35	2.90	4.11	3.51	3.45	5.56	10.53	45.30	7.09	13.33	14.75	11.63	5.56	7.81	9.52	8.99	8.36	2.94	16.67	41.40	13.95	8.46
Amphora	1.89	5.80	4.35	2.90	4.11	5.26	8.62	5.56	3.16	1.28	3.94	4.0	--	2.33	--	--	3.17	2.24	--	2.94	--	--	--	--
Pleurosigma	1.89	7.25	2.90	8.70	10.95	8.77	5.17	3.70	7.37	0.85	7.87	4.0	8.20	9.30	5.56	14.06	9.52	10.11	8.36	11.76	11.46	3.79	17.05	9.86
Skeletonema	--	8.70	1.45	4.35	5.48	5.26	5.17	3.70	3.16	0.43	7.09	6.67	4.92	4.65	--	3.12	6.35	5.62	5.02	--	3.12	--	10.08	5.64
Peridinium	--	1.45	4.35	4.35	2.75	1.75	--	3.70	7.37	3.42	8.66	4.0	3.28	--	--	--	1.59	3.31	--	8.82	5.21	2.96	--	--
Lyngbya	5.66	4.35	4.35	5.80	9.58	7.02	8.62	7.41	5.26	2.99	5.51	--	--	--	--	--	1.59	1.12	3.34	--	--	--	--	--
Asterionella	--	--	4.35	2.90	4.11	--	1.72	1.85	--	--	4.72	--	--	--	--	--	--	--	5.02	2.94	--	--	--	--
Ceratium	--	4.35	1.45	1.45	2.75	1.75	--	--	--	0.85	2.36	4.0	--	--	--	1.56	--	1.12	--	--	--	--	--	--
Oscillatoria	5.66	4.35	1.45	2.90	2.74	--	10.34	5.56	2.11	--	--	--	--	--	--	--	--	2.24	--	--	--	--	--	--
Chaetoceros	--	4.35	7.25	2.90	4.11	--	--	1.85	1.05	0.85	7.09	6.65	--	4.65	--	3.12	4.76	5.62	15.05	--	6.24	0.51	3.10	5.64
Bacteriastrum	--	4.35	7.25	2.90	4.11	--	--	1.85	--	2.56	--	2.67	--	--	--	--	--	--	--	--	7.29	1.29	1.55	11.28
Dinophrys	--	--	--	2-90	--	--	--	1.85	1.05	0.43	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cymbella	--	1.45	1.45	--	1.40	3.51	6.89	5.56	2.11	0.85	--	13.33	--	--	--	--	--	--	--	--	--	--	--	--
Polysiphonia	--	--	--	1.45	1.40	1.75	1.72	1.85	--	--	--	--	3.28	--	--	--	3.17	2.24	--	--	--	--	--	--
Biddulphia	--	--	7.25	1.45	--	--	1.72	1.85	16.84	8.55	4.72	1.33	--	--	5.56	1.56	--	5.62	3.34	--	6.24	31.05	6.20	--
Lauderia	--	--	--	--	--	3.51	--	1.85	--	0.85	0.79	--	1.59	1.12	--	--	--	--	--	--	--	--	--	--
Mastogloia	--	2.90	1.45	--	--	--	1.72	1.85	--	--	--	1.33	--	--	--	6.25	--	1.24	--	--	--	--	--	--
Trichodesmium	1.89	2.90	1.45	--	--	--	8.62	5.56	3.16	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Proplectella	--	--	1.45	--	--	3.51	--	--	--	--	--	--	--	--	--	--	--	5.62	--	--	--	0.37	--	--
Thalassiosira	9.43	7.25	2.90	2.90	1.40	1.75	--	1.85	--	--	10.24	1.33	3.28	4.65	5.56	--	1.59	2.24	5.02	--	1.04	--	19.38	--
Guinardia	--	--	2.90	--	--	--	--	--	--	--	--	1.33	--	--	--	--	--	--	--	--	--	--	--	--
Diploneis	7.54	2.90	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Surirella	--	--	--	2.90	--	5.26	1.72	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Brachyonus	--	--	--	2.90	4.11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	12.5	--	--	--
Rabdonema	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.37	--	--
Noctiluca	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.78	--	--

The maximum occurrence of Rhizosolenia in the plankton was noticed in April in both the years, whereas in all the other months they were rather insignificant in the plankton. Pleurosigma, though it was found in the plankton throughout the period of this study, yet their numbers in the water were very low. The maximum was found in November '80, October '81, May '82 and May '82. The maximum occurrence of Skeletonema was found during the summer months of May and June in both the years. Apart from the above, Chaetoceros, Peridinium, Bacteriastrum, Amphora, Thalassiosira, Biddulphia, Lyngbya, Polysiphonia, Cymbella and Dinophrys make their occurrence sporadically in the plankton. Some of the plankters appear to be very seasonal and their number is very low when compared to the other species in the plankton. Diatoms like Oscillatora, Ceratium, Lauderia, Mastogloia, Guinardia, Diploneis, Bacillariales, Trichodesmium, Rabdonema, Noctiluca appear in in certain seasons only.

Among the zooplankters copepods, nauplius larvae form the bulk, and occur in the plankton with wide fluctuations (Table 2). Both the bivalve and gastropod veligers were observed throughout the period of study and these veligers showed very high percentage in November and in May in both the years. Tintinnopsis, a ciliate, seems to be seasonal and its primary peak was in October '80 and September '81 and the secondary peak was in Mardh & April,

Table. 8

Monthly variations in the percentage of occurrence of zooplankton in the Pulicat Lake.

Zooplankton	Month and Year																					
	July'80	Aug.	Sept.	Oct.	Nov.	Dec.'	Jan.'81	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan'82	Feb.	Mar.	Apr.	May	June
Copepod	34.48	31.11	42.11	38.88	48.39	77.78	52.94	65.12	67.05	72.29	41.00	55.57	37.04	43.33	38.89	47.52	55.42	48.89	57.89	55.45	42.22	69.87	57.77	64.6
Eggs	41.37	44.44	36.84	5.55	3.23	-	29.41	9.30	-	2.41	6.69	7.10	7.41	23.33	16.67	0.99	2.70	12.50	9.26	4.55	15.74	5.30	-	-
Nauplius	-	4.44	7.89	16.67	6.45	5.56	2.94	-	8.[illegible]	10.00	21.38	6.56	-	6.67	5.56	-	4.05	16.67	15.79	-	17.77	10.60	5.33	14.3
Tintinnopsis	10.35	4.44	7.89	16.67	9.68	-	8.82	4.65	6.81	8.07	11.03	7.65	-	3.33	19.44	5.94	2.70	-	-	8.18	19.44	13.25	5.67	9.5
Polychaete larvae	-	-	2.63	-	-	-	-	-	-	-	1.38	1.09	-	-	-	-	-	0.69	-	-	-	-	-	-
Bivalve veliger	-	2.22	2.63	16.67	32.26	16.67	5.88	2.33	8.94	7.23	15.17	1.09	7.41	3.33	5.56	25.74	31.08	14.31	10.04	6.06	1.85	1.99	22.22	7.1
Gastropod veliger	13.79	4.44	-	-	-	-	-	16.28	7.32	-	6.97	6.56	37.04	20.00	5.56	19.80	4.05	6.25	7.02	25.76	11.11	-	6.78	2.4
Lucifer	-	-	-	-	-	-	-	2.33	1.63	-	-	6.55	-	-	2.78	-	-	0.69	-	-	0.93	-	2.22	1.2
Lysis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cypris larvae	-	4.44	-	5.55	-	-	-	-	-	-	1.38	1.64	11.11	-	5.56	-	-	-	-	-	0.93	-	-	0.6
Fish larvae	-	4.44	-	-	-	-	-	-	-	-	-	2.19	-	-	-	-	-	-	-	-	-	-	-	-

in both the years. Apart from the above, Lucifer, Cypris larvae and polychaete larvae make their occurrence sporadically.

Plankton showed mainly two peaks in the year, the primary one was in March-April and the secondary one was in November-December. The diatoms also showed bimodality in their seasonal occurrence as is illustrated in Fig 1. The primary peak was in March to May and the secondary one was in November-December. The peak occurrence of diatoms was followed by the peak of zooplankton. More or less, similar seasonal variations in the plankton were reported by Prasad (1956) in the Gulf of Mannar and by Krishnamurthy (1967) in the Vellar estuary.

PLANKTON IN RELATION TO HYDROGRAPHY

The primary production of the sea or estuary is influenced by various parameters such as the physical, chemical, and biological parameters. Only three parameters viz., salinity, temperature and oxygen were related to the plankton production of the Pulicat lake during this study

The salinity range was observed between 0.37‰ and 39.24‰, the range of water temperature was between 23°C and 30.5°C, and oxygen was between 3.19 ml/l and 8.83 ml/l during the two years of study(Fig 2 and Table 3). Since

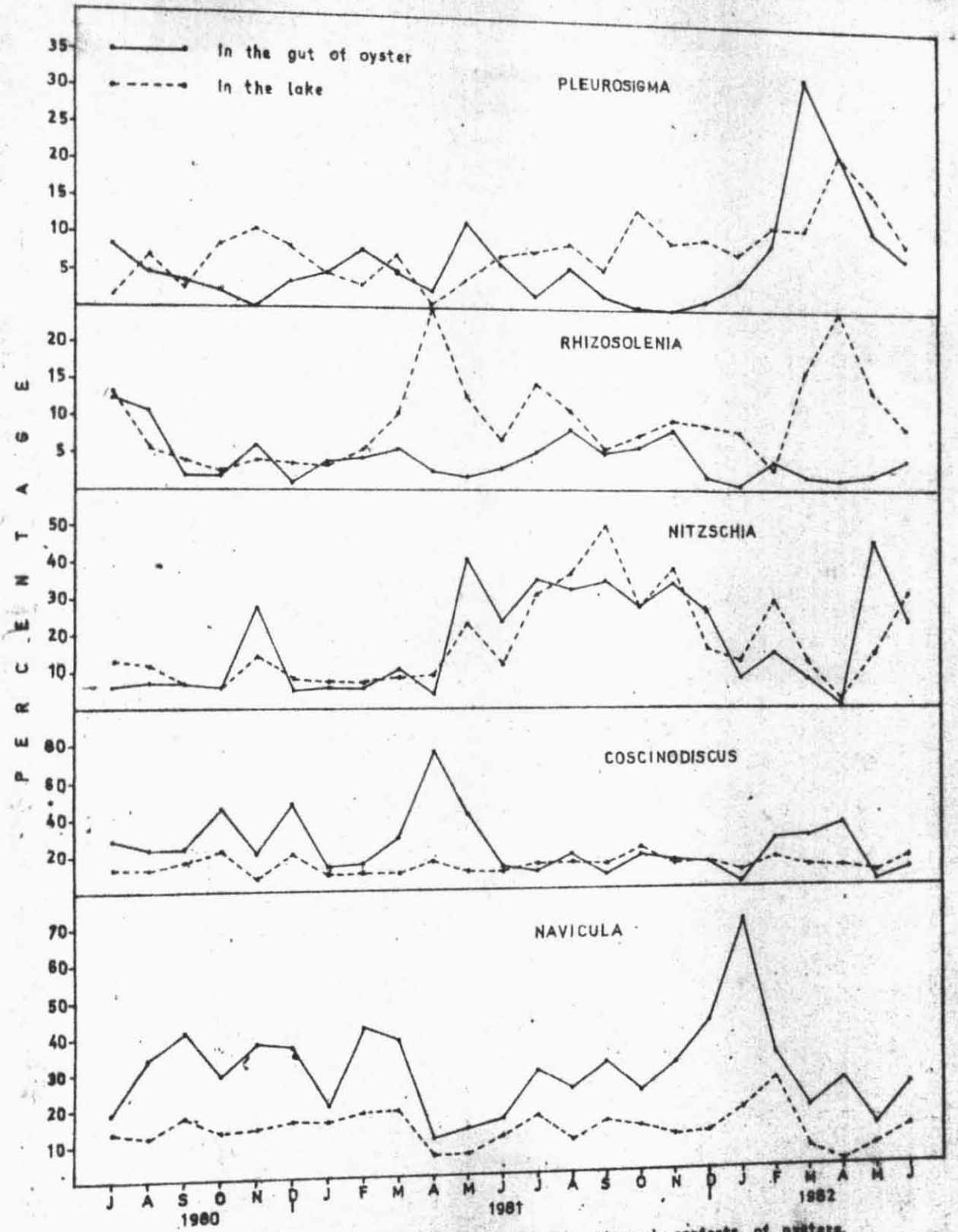


Fig. 1 Occurrence of the dominant diatoms in the stomach contents of oysters, C. madrasensis in the Pulicat lake, during July 1980 – June 1982.

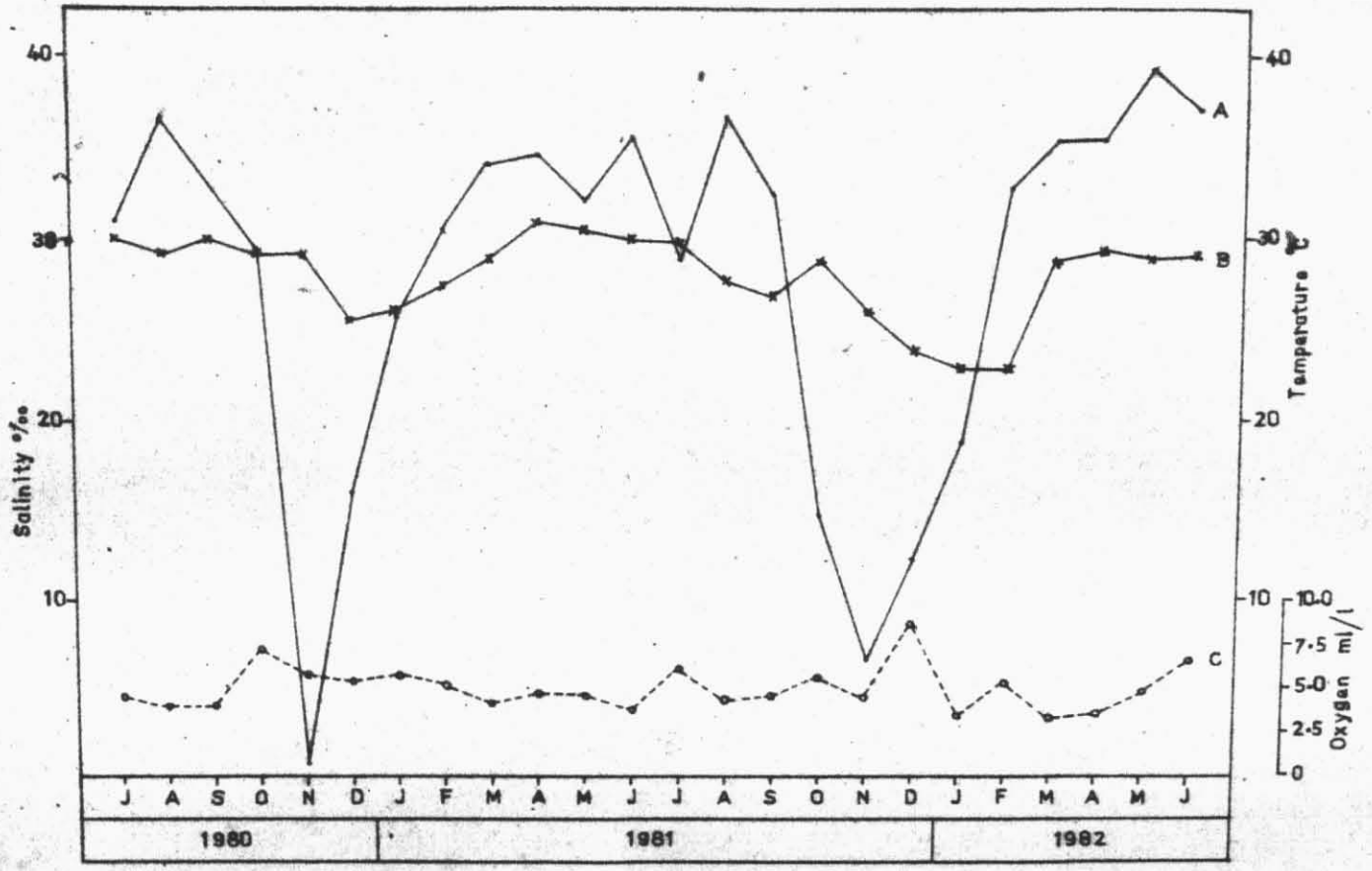


Fig.2 Seasonal variation in the Salinity, Temperature and Oxygen over the oyster bed in the Pulicat lake, during July 1980 to June 1982.

A. Salinity B. Temperature C. Oxygen

Table. 3

Monthly variations in salinity, temperature and Oxygen observed in the oyster bed at pulicate lake.

Months		Salinity ‰	Temparature (°C)		Oxygen (ml/l)
			Atmosphare	Water	
July	1980	31.06	28.0	30.0	4.65
August		36.56	28.3	29.3	4.14
September		32.95	29.0	30.0	4.03
October		29.56	28.0	29.5	7.43
November		0.37	27.5	29.5	4.99
December		16.02	27.0	25.8	4.42
January	1981	25.74	27.5	26.0	4.70
February		30.39	30.5	27.5	5.22
March		34.14	29.5	29.0	4.20
April		34.83	29.0	31.0	3.97
May	32	32.21	33.5	30.5	4.65
June		35.42	30.3	30.0	3.91
July		29.20	28.0	29.8	5.16
August		36.53	27.8	27.8	4.31
September		32.65	28.5	27.0	4.76
October		14.99	27.3	29.0	5.57
November		6.83	27.3	26.0	4.48
December		12.41	22.5	24.0	8.83
January	1982	18.99	21.0	23.0	3.19
February		32.84	21.0	23.0	5.22
March		35.29	27.0	29.0	3.19
April		35.39	28.3	29.5	3.82
May		39.24	31.5	29.0	4.71
June		37.19	27.0	29.0	6.49

the lake has shown very wide fluctuations in all these parameters, the primary production and the secondary production also were found to be closely dependent upon these parameters.

The range of salinity during the primary peak of diatoms was recorded in between 32.2‰ and 39.24‰, and during the secondary peak, the salinity was ranging between 0.37‰ and 16.02‰. Temperature was between 28.5°C and 33.5°C, and between 27°C and 32.75°C, and the dissolved oxygen was ranging between 3.97 ml/l and 4.71 ml/l and between 4.42 ml/l and 8.83 ml/l during the primary peak and secondary peaks respectively. Both phytoplankton and zooplankton showed an apparent positive correlation with salinity and temperature. In the summer months of April, May and June, the salinity and temperature were high in the lake, as a result of which the planktonic production was also considerably high. Immediately after the monsoon season plankton production was slightly higher during the months of November, December and January. Most of the marine forms of diatoms disappear in the lake due to the prevalence of freshwater in the lake during the monsoon. Only those which can tolerate the lake environment were found to be in good numbers.

NATURAL FOOD OF OYSTERS

Edible oysters are sessile and hence are filter feeders, generally feeding on the suspended particles

available in the water in which they live. However, they are selective feeders on diatoms and detritus. The animal types and diatoms constituting the stomach contents of oysters were identified upto the generic level, their percentage of occurrence and the index of relative importance are given in the Table 4 & 5). Based on the stomach contents of 682 oysters the natural food of oysters in the Pulicat lake was determined to be 52.8% diatoms, 45.7% detritus and 1.5% animal matter (Fig 3).

DETRITUS: The percentage of detritus and unidentifiable plant matter in the gut of oysters was estimated to be 45.7%. Monthly variations in the percentage composition of diatoms, detritus and zooplankton from the gut of oysters is given in Table 6. Oysters with more than 50% detritus matter in the stomachs were about 43.59%. The maximum number of oysters with 50% detritus in their stomachs were found in July '81, August '81 and in February '82. The other 56.41% contain both diatoms and zooplankton.

The organic and inorganic detritus, was perhaps consumed from the water column, opening the valves frequently. Higher percentage of detritus was found in August and February during both the years. The quantity of detritus was very low just previous to monsoon and as well as during the summer months.

Apart from detritus, other contents in the gut of the oysters are diatoms and zooplankton. Among the

TABLE 4

PERCENTAGE OF OCCURRENCE OF EACH FOOD ITEM IN THE GUT OF C. MADRASENSIS

MONTH & YEAR	NO. OF GUTS EXAMINED	FOOD ITEMS																									
		NAVICULA	COSCINODISCUS	NITZSCHIA	AMPHORA	PERIDINIUM	RHIZOSOLENIA	PLEUROSIGMA	THALASSIOSIRA	CHAETOCEROS	PROROCENTRUM	SKELETONEMA	BIDDULPHIA	[illegible]	CYMBELLA	DITYLUM	[illegible]	BACILLARIASTRUM	DIPLONEIS	CERATIUM	BACILLARIALES	NOCTILUCA	VILLERSIA	TINTINNOPSIS	COPEPODS	EGGS	POLYCHAETE LARVAE
JULY 20 1980	20	100.0	100.0	87.5	79.2	-	100.0	100.0	-	-	33.3	-	-	-	45.8	50.0	8.3	83.3	-	-	-	-	-	12.5	-	-	-
AUG. 27	27	100.0	100.0	77.8	85.2	-	70.4	59.3	-	-	-	-	-	29.6	11.1	-	-	48.2	-	-	-	-	-	18.5	-	-	-
SEP. 30	30	100.0	100.0	93.3	100.0	46.7	60.0	73.3	-	-	-	-	-	33.3	66.7	73.3	66.7	33.3	-	-	-	-	-	-	-	-	-
OCT. 35	35	97.1	100.0	62.9	57.1	-	22.9	31.4	8.6	-	17.1	17.1	-	-	20.0	-	-	5.7	5.7	-	-	-	11.4	-	-	-	-
NOV. 20	20	100.0	100.0	100.0	50.0	-	60.0	-	-	-	15.0	-	30.0	-	-	-	-	-	-	-	-	-	60.0	-	-	-	-
DEC. 30	30	100.0	100.0	96.7	83.3	10.0	56.7	80.0	-	-	-	10.0	-	-	3.3	13.3	23.3	-	16.7	3.3	-	-	36.7	-	-	-	-
JAN 1981	30	100.0	100.0	100.0	93.3	46.6	100.0	100.0	-	-	-	-	-	-	-	53.3	-	-	-	-	-	-	6.7	93.3	-	-	-
FEB. 30	30	93.3	93.3	76.7	93.3	50.0	70.0	86.7	-	-	-	-	-	-	20.0	43.3	10.0	3.3	10.0	-	-	-	26.7	6.7	-	-	-
MAR. 30	30	93.3	96.7	66.7	43.3	40.0	33.3	50.0	-	-	-	-	-	-	-	6.7	-	-	16.7	-	-	-	-	13.3	-	-	-
APR. 25	25	64.0	100.0	56.0	-	-	36.0	24.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48.0	-	-	-	-
MAY 25	25	76.0	100.0	-	48.0	28.0	56.0	56.0	-	48.0	52.0	-	68.0	-	-	-	-	-	-	-	92.0	-	36.0	84.0	-	4.0	-
JUNE 30	30	100.0	100.0	100.0	36.7	100.0	76.7	90.0	30.0	-	33.3	13.3	46.7	-	-	-	23.3	-	-	26.7	13.3	-	30.0	20.0	-	-	-
JULY 36	36	97.2	66.7	88.9	30.5	47.2	55.6	33.3	2.9	-	72.2	13.9	-	-	22.2	-	8.3	-	5.6	-	-	-	2.8	-	-	-	-
AUG. 26	26	88.5	76.9	92.3	80.8	3.9	57.6	53.8	11.5	15.4	-	-	-	-	-	-	-	3.9	-	3.9	-	-	15.4	-	3.9	-	-
SEP. 20	20	100.0	100.0	100.0	15.0	70.0	60.0	60.0	20.0	-	20.0	40.0	-	-	15.0	-	20.0	-	-	-	-	-	-	-	-	-	25.0
OCT. 32	32	100.0	93.8	100.0	25.0	75.0	75.0	12.5	31.3	-	81.3	-	37.5	-	18.8	-	43.8	-	-	-	37.5	-	37.5	-	-	-	-
NOV. 33	33	30.3	30.3	33.3	6.1	-	24.2	-	-	-	24.2	-	12.1	-	-	-	15.2	-	-	-	3.1	-	15.2	-	-	-	-
DEC. 24	24	50.0	45.8	50.0	50.0	29.2	20.8	20.8	-	-	-	16.7	54.2	-	-	-	58.3	-	-	-	-	25.0	16.7	-	-	8.3	4.0
JAN. 1982	30	100.0	86.7	100.0	66.7	-	20.0	86.7	-	-	73.3	-	-	-	-	60.0	-	-	-	-	-	-	36.7	-	-	-	-
FEB. 20	20	80.0	40.0	50.0	35.0	-	50.0	80.0	-	-	-	-	-	-	-	-	10.0	-	-	-	-	-	10.0	-	-	10.0	-
MAR. 32	32	65.6	68.8	62.5	28.1	-	25.0	62.5	-	-	-	6.3	12.5	-	-	31.3	6.3	-	-	-	-	-	18.8	37.5	-	-	-
APR. 41	41	63.4	70.7	61.0	-	14.6	14.6	78.1	-	-	7.3	-	-	19.5	-	-	-	-	-	-	34.2	7.3	2.4	29.3	19.5	-	-
[illegible]	[illegible]	[illegible]	62.5	93.8	-	43.8	43.8	87.5	-	75.0	-	-	68.8	-	-	-	-	-	-	-	75.0	-	62.5	81.3	-	-	-
[illegible]	[illegible]	70.0	45.0	70.0	25.0	60.0	40.0	50.0	-	-	-	-	45.0	50.0	-	-	-	-	-	-	30.0	-	30.0	-	-	-	-

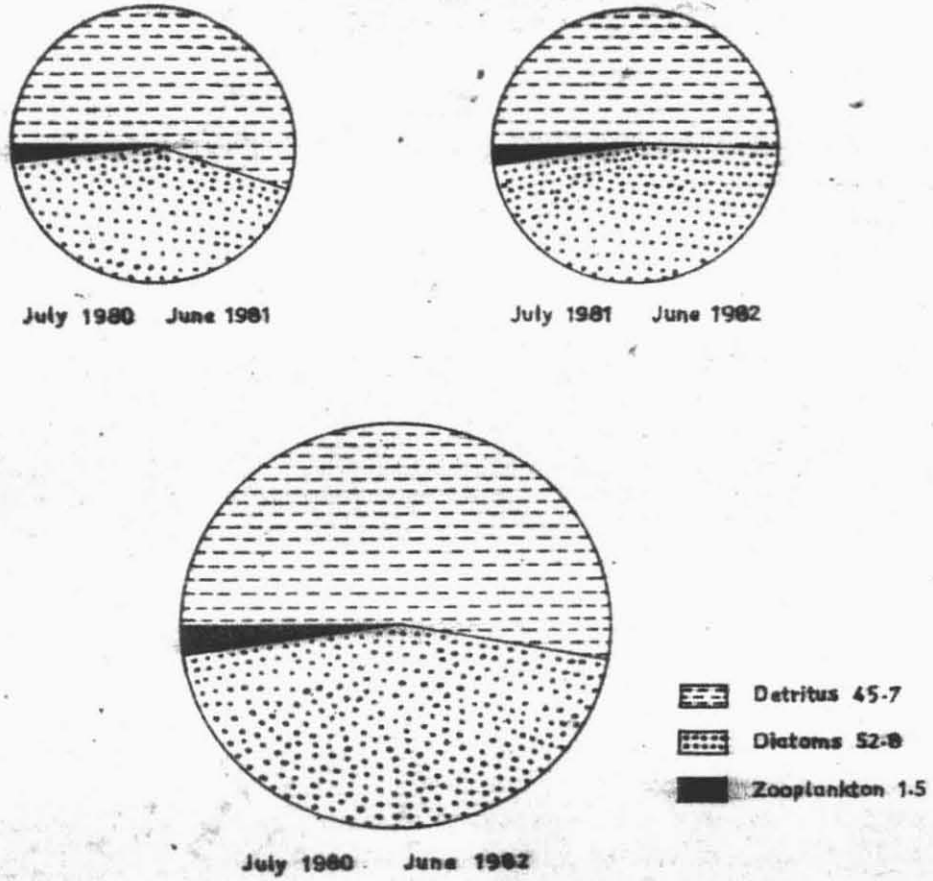


Fig. 3 Percentage composition of major components of food in the gut of the oyster, C. madrasensis.

Monthly variations in the percentage composition of detritus, diatoms and zooplankton observed in the gut of oysters; each value represents an average estimate of oyster sample containing 20 to 41 individuals.

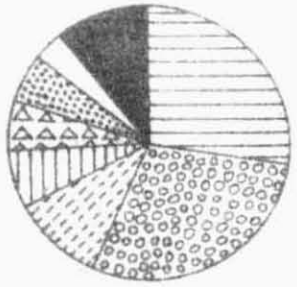
Month & Year	Detritus (%)	Diatoms (%)	Zooplankton (%)
July 1980	41.25	57.04	1.71
August	48.75	50.47	0.78
September	36.67	63.33	—
October	39.67	60.01	0.32
November	47.50	51.51	0.99
December	44.00	55.58	0.42
January 1981	47.58	48.52	3.90
February	62.75	36.69	0.56
March	44.33	55.22	0.45
April	36.67	60.36	2.97
May	42.50	53.41	4.09
June	28.00	70.57	1.43
Average	43.31	55.23	1.47
July	40.00	59.97	0.03
August	64.56	34.74	0.70
September	47.50	51.79	0.71
October	47.81	51.02	1.17
November	53.90	45.48	0.62
December	47.50	52.18	0.32
January 1982	45.42	53.95	0.63
February	54.50	41.23	4.27
March	54.17	44.14	1.69
April	48.25	48.79	2.96
May	41.56	53.89	4.55
June	32.00	67.35	0.65
Average	48.09	50.38	1.53
Average for 2 years	45.70	52.80	1.50

diatoms the order of preference was Navicula, Coscinodiscus, Nitzschia, Pleurosigma, Rhizosolenia, Amphora and Peridinium (Table 5). As per the index, oysters preferred either Navicula or Coscinodiscus, whichever was abundant in the environment. However, the other plankters such as Prorocentrum, Bacteriastrum, Detonula, Cymbella, Rabdonella, Diploneis, Chaetoceros, Thalassiosira and Skeletonema etc., also occurred in the gut of these oysters but their occurrence, as the food of oysters, was very seasonal. Noctiluca and Ceratium were noticed only very rarely in the stomach of oysters.

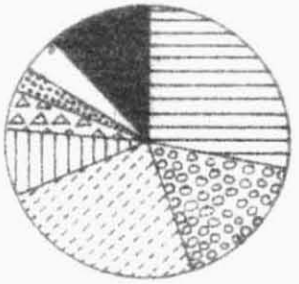
Among the zooplankters, the bivalve veligers rank first and the next is Tintinnopsis. The occurrence of copepods and the polychaete larvae in the gut of oysters was noticed twice during the period of this study. The index showed the maximum occurrence of bivalve veligers during the months of November '80 and February, May, August, October '81 and February and May 1982. The peak occurrence of Tintinnopsis was during the month of April and May during both the years of study.

SEASONAL VARIATIONS IN THE FOOD OF OYSTERS

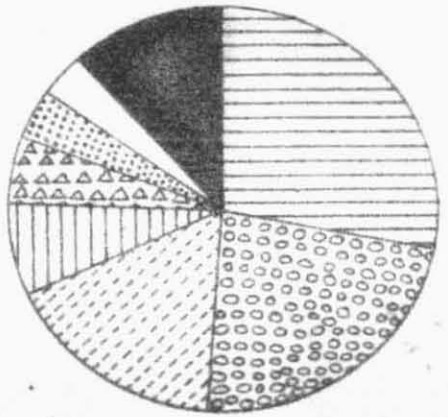
The important diatoms which constitute the food of the oysters and their fluctuations both in the environment as well as in the gut of the oysters are illustrated in Fig 1. The important diatoms (Fig.4) forming the food



July 1980 — June 1981



July 1981 — June 1982



July 1980 — June 1982

Navicula 27·72
Coscinodiscus 23·41
Nitzschia 17·09
Pleurosigma 6·85
Rhizosolenia 5·37
Amphora 3·95
Peridinium 3·53
Misc. food items 12·08

Fig. 4 Percentage composition of the dominant diatoms in the gut of the oyster, C. madrasensis

of oysters viz., Navicula, Coscinodiscus, Nitzschia, Pleurosigma, Rhizosolenia and Amphora, made their appearance throughout the period of this study with their usual fluctuations. Thus the peak of these diatoms in the environment coincided with their peak in the gut of the oysters also. However, the oysters showed selective feeding in certain seasons, especially in May 1981, during which the percentage of Peridinium was 8.66 in the environment, which is lower than the other diatoms such as Nitzschia, and Coscinodiscus, but the gut of the oyster was rich in Perdinium.

Navicula forms a very important food diatom, ranking first, in the gut of oysters. The abundance of this diatom in the gut of oysters was in September, January and February during both the years of study. The percentage of the same diatom was also found to be high in plankton during the same period in the open lake waters whereas the other diatoms were found in lesser quantities. In September '81, the percentage of Nitzschia was found to be 50 whereas all the other diatoms together made up the other half. In January '82, the Navicula in the index table 5 was found to be very high and at the same time the water showed only 16.72 percent, since all the other diatoms were found low in the water. The oysters preferred Navicula which was abundant comparatively, thus forming the bulk of the constituents of the stomach. In the subsequent month, the abundance of Navicula showed slightly higher

percentage than in the previous month whereas the other items such as Coscinodiscus and Nitzschia increased considerably.

Coscinodicus was found throughout the year with some fluctuations in its numbers. The abundance of Coscinodiscus in the oyster gut reflected an equal abundance in the environment also. The peak occurrence of this diatom in the gut of the oysters was found in April in both the years, but during this period the percentage of the other diatoms was found to be lower. In the lake waters, Rhizosolenia was found to be 45.3% in 1981 and 41.4% in 1982, but their occurrence in the oyster food was very low, and this showed that the oysters preferred Coscinodiscus only, even though Rhizosolenia occurred abundantly in the environment.

Nitzschia is a major food item that showed a very wide fluctuation both in the water as well as in the gut of oysters during the two years of observation. There were two peak of occurrences of this diatom in the food of oysters. The first peak was during November and the second peak was in June in the first year, whereas in the second year the higher peak was in September and the lower in May'82. The percentages of Nitzschia and Navicula was in equal proportions in the water, as also in the gut of the oysters. These diatoms were represented more or less equally in November'80.

In June Nitzschia was slightly higher than Navicula, and the same was reflected in the lake also. In September '81, maximum percentage of Nitzschia was found in the waters, and equally well represented in the gut of oysters also.

Rhizosolenia was observed in the gut of oysters with the greatest seasonal variations. The maximum abundance of this diatom was observed during June-August and November'80 and in February and March '81. Rhizosolenia showed a single peak in April during the year. Though they occur in large quantities, the guts of oysters do not adequately reveal the abundance of the diatoms in the environment. During this period the oysters avoided the food item Nitzschia and preferred Coscinodiscus which was abundant in the environmemt. Rhizosolenia forms the food along with the other important items of food such as Coscinodiscus and Navicula, but it was not greatly preferred by the animal though they were abundant in certain months.

Pleurosigma is another important food constituent which was very well relished by the oysters and was also found throughout the period of this study. The peak occurrence was observed during October/November and in May in the lake waters during the two years of observation. In the food of oysters it showed some wide fluctuations in all the months. The maximum number of Pleurosigma was observed in the stomachs of oysters during July, February and April during the second year. The percentage of Pleurosigma was 12.81 during May '81, thus in quantity it

was the third abundant food item in the gut of oysters. It was also found more than any other diatom in the gut during March '82, but at the same time in the water it was found even fewer than the Rhizosolenia and Nitzschia. Avoiding these two, the oysters preferred Pleurosigma during this period.

Amphora showed a peak period of occurrence in the gut of oysters during January '81. Its percentage in the food was 3.95 and takes the sixth place as the food item of oysters. The maximum percentage of this diatom in the lake water was found during January and February. This seems to reach the gut of oysters along with the other oyster food items which form the bulk of the stomach contents.

Peridinium is another diatom that occurred in the food of oysters but there was no regularity throughout the season. Whenever there was a peak period of its occurrence in the water, it was reflected in the stomachs of the oysters also. The maximum percentage of this food item was observed during June '81. The gut contents of the oysters during this period was dominated by the presence of Peridinium. In the environment the presence of this diatom was less compared to Nitzschia and Coscinodiscus. However, the bulk of the gut contents dominated by this diatom indicated that the oysters preferred Peridinium, even when the other regular food items were available in the water.

The other important food items of oysters were Biddulphia, Bacteriastrum, veligers and Tintinnopsis. The percentage of occurrence of these diatoms and zooplankters in the gut was directly proportional to their occurrence in the environment. Tintinnopsis was found maximum in the month of May during the two years of observation, but in all the other months it was found in lesser quantities. Bivalve veligers also showed the peak during the month of May and October/November whenever there was the spawning of oysters in the lake.

The stray occurrence of copepods, polychaete larvae, crustacean appendages, eggs, Ceratium, and Noctiluca was also noted in the oyster guts. This occurrence in the gut may be due to their accidental entry along with the other food items.

Though the oysters feed on whatever food is available in the water yet they have the capacity to select the most preferred food through their labial palps. Oysters prefer Pleurosigma, as their food. This is evident by the presence of plenty of Pleurosigma in the gut of oysters during May '81 whereas this particular diatom was low in the surrounding water, while the other items such as Nitzschia and Coscinodiscus were more abundant in the environment. Again, the percentage of Rhizosolenia in the lake was 16.67 and 41.4, and Coscinodiscus was 12.5 and 10.7 in

in March and April '82 respectively. In the gut of oysters the percentage of Pleurosigma was 33.37 and 22.22 in the month of March and April respectively but during the same period the percentage of Rhizosolenia was 1.77 and 1.44 respectively, showing the selectivity for Pleurosigma.

The percentage of Rhizosolenia was found to be high during the month of April 1981, but the index-table showed very low incidence of this diatom in the food. Coscinodiscus was abundant only by one-third of the Rhizosolenia, but ye the dominant food item during this period was Coscinodiscus. Thus the oysters showed selectivity in feeding by taking the less concentrated Coscinodiscus and avoiding the highly concentrated Rhizosolenia in the water.

The percentage of Peridinium was 8.66 and 4.0 in May and June '81 and Nitzschia and Coscinodiscus were equally dense only upto 11.81% in the plankton. In the food of the oysters however, Peridinium was very much dominant. It formed 28.53 whereas Nitzschia and Coscinodiscus in the gut of oysters were 24.85% and 13.05% respectively. The oysters have shown preference to Peridinium eventhough the other diatoms were found abundant in the plankton.

FEEDING INTENSITY

Based on the two years of study, two peaks of intensity of feeding were noticed, one during December and January and the other during May and June (Fig 5). The occurrence of phytoplanktonic food organisms may be poor, but the oysters have shown high filtering capacity during their peak period of feeding. The high feeding during December and June was mainly due to the great abundance of diatoms such as Navicula, Coscinodiscus and Pleurosigma. Poor feeding was observed during October and November and this was probably due to prevalence of freshwater influx into the lake. Oysters probably close the valve very tightly to overcome the unfavourable conditions during this period.

Though a high diatom population occurs during the monsoon, yet if the silting also was very high which is detrimental to the oysters, there were ways of avoiding food during this period. The intensity of feeding was also less in August during the two years. This may be due to the low occurrence of diatoms probably because of the prevalence of higher salinity and temperature. During February and March also poor feeding was observed and this was mainly due to the interaction of these two factors in the environment. The primary factor was that the oyster bed exposed during most of this time, and secondly the diatoms were found to be very poor in the environment.

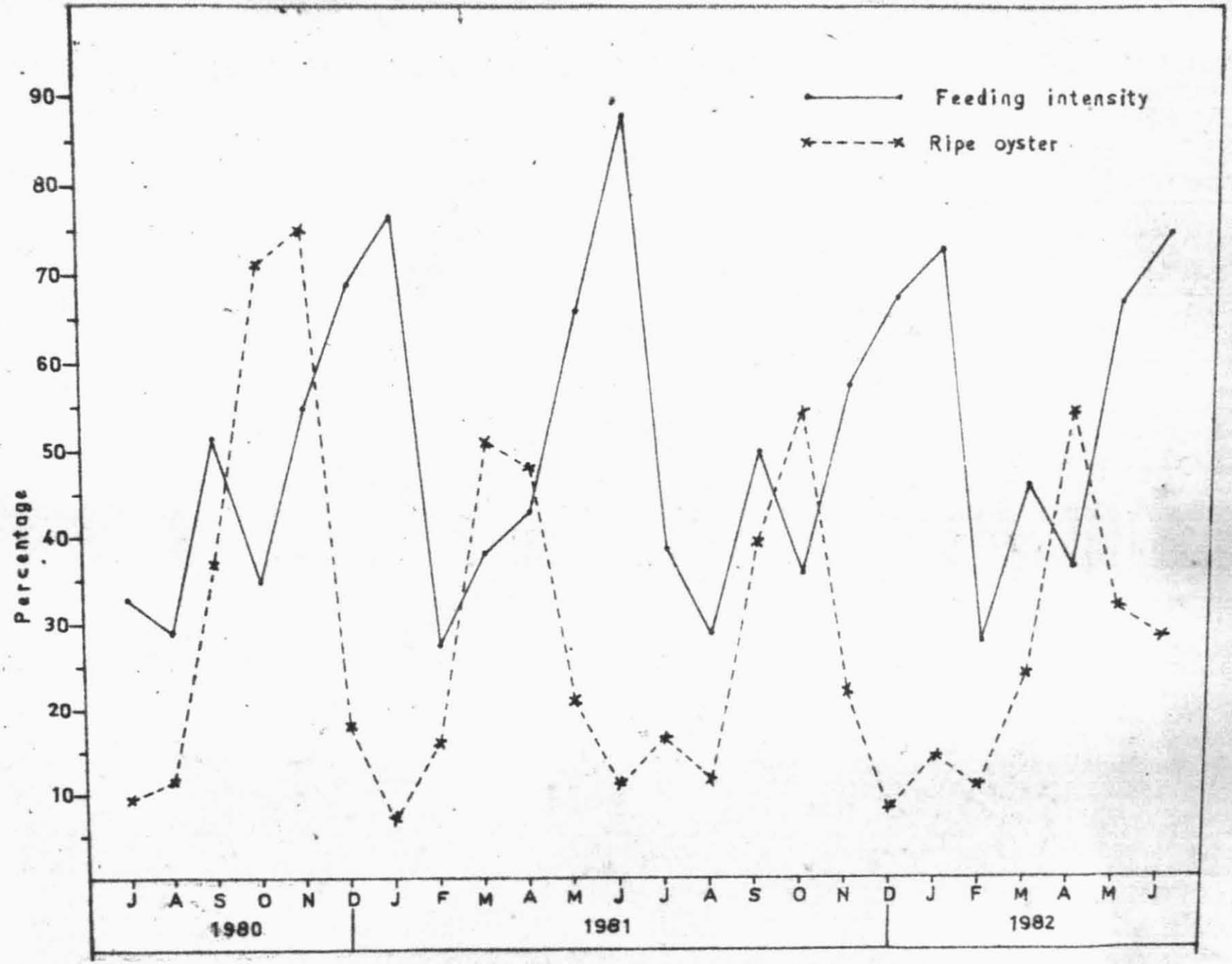


Fig.5 Relative percentage of the feeding intensity and the occurrence of ripe oysters C.madrasensis in the Pulicat lake

FEEDING INTENSITY AND CONDITION OF GONAD

Gametogenesis was very active during August and September 1980 and '81, and the energy required for the same was supplied by the intake of enormous food during January from the environment. This energy was obtained from the dominant food constituents like Nitzschia, Navicula and Coscinodiscus, whereas all other diatoms were found in lesser numbers. When the majority of oysters attain the ripe condition the intensity of feeding was found to decline in October of both the years(Fig 5). Spawning occurred during October and November immediately after the outbreak of the monsoon rains and when the salinity came down in the lake incidentally reducing the intensity of feeding in the oysters. Immediately after the spawning was over the feeding intensity was found to be rising, reaching a very high level in December '80, December '81 and January '82. This high feeding was mainly to meet the energy lost in connection with the egg formation and releasing of eggs during the spawning season. The major food items of oysters during this period were Navicula, Coscinodiscus and Nitzschia. During the period of gametogenesis i.e., February and March '82, the intensity of feeding was contributed by the same items of food, and their order of preference was Navicula, Coscinodiscus, Nitzschia and Pleurosigma. The decline in the food constituents in the gut of the oyster during February my be probably due to the over expósure of

oysters during the low tide and also due to lack of proper supply of diatoms by the tidal water in the oyster-bed. During this period the energy source would have been the reserved food in the hepatopancreas. Again the intensity of feeding was very high immediately after the spawning during April and May, and during this period the major food constituents in the stomachs of oysters were Coscinodiscus, Navicula and Pleurosigma.

It is clear that the oysters feed actively during the period of gametogenesis, but feeding was low when the oysters reach the ripe condition. Oysters shows poor feeding during the monsoon season due to the prevalence of the low saline waters. During the post spawning season oysters feed very intensively again to meet the energy spent during spawning.

DISCUSSION

Estuaries, although usually rich, fluctuate widely in nutrient supply and in temperature and salinity regimes, and hence also in kinds and quantities of food available. The fauna of the estuaries also varies from season to season according to the availability of food and they are also accustomed to face a complex environment at times. Quayle (1980) mentioned that little is known about the usable food of oysters. The main subject

such as food preference and utilization, dispersion of larvae, and aggregation of spat and genetics are poorly known.

Whatever be the actual food, whether it is diatoms or microscopic organisms or detritus from the disintegration of plants and animals, there is usually an annual food cycle. The reproductive status of oysters also decides the food items to be taken by the oysters. In the tropical countries, since light and temperature are relatively constant throughout the year, salinity among the other factors, is more important in influencing the abundance of food and feeding intensity of oysters. In the Pulicat lake, salinity plays a great role during the monsoon season in limiting the feeding of oysters, whereas it plays an equally great role in producing a plankton peak during the summer months.

Oysters are sedentary in nature and feed on the suspended organisms and detritus in the water, thus detritus froms the major constituent of the food of oysters. The high percentage of detritus in the gut of oysters from the environment suggests that detritus is the most important food item of oysters. The same has been reported by Hoek (1883) in the European oysters, Hornell (1908) at Pulicat, Blegvad (1914) in the Danish waters, Moses (1928) at Madras, and Durve (1964) on the Bombay oyster C. gryphoides. However in the Pulicat lake oysters the

the percentage of detritus was found to be 45.7 which however showed fluctuations during the entire period of study.

Orton (1935) studied the food of oysters and found that the main diatom on which oysters feed are Nitzschiella parva, Pleurosigma, Coscinodiscus, Chaetoceros, Rhizosolenia, Melosira and Prorocentrum, and among protozoans Tintinnopsis. Devanesan and Chacko(1955) studied the food of oysters, C. madrasensis and listed the diatoms such as Rhizosolenia, Coscinodiscus, Chaetoceros, Bacillariales, Biddulphia, Nitzschia, Pleurosigma and Guinardia. Durve(1964) observed the major food items such as Coscinodiscus, Thalassiosira, Biddulphia, Coconeis, Achnanths, Diploneis and Synedra in the gut of oysters, C. gryphoides from the Bombay coast. In the Pulicat lake oysters, the order of food preference was Navicula, Coscinodiscus, Nitzschia, Pleurosigma, Rhizosolenia, Amphora and Peridinium, among protozoans Tintinnopsis, and lastly veliger larvae.

During the monsoon the detritus was at a moderate level and the production was low as a result of low saline media in the lake and hence the feeding was also poor in the oysters. Similar observations were made by Durve (1964) in C. gryphoides during the monsoon season. The occasional presence of copepods and crustacean appendages were noticed during the two years of observation.

The presence of protozoan and metazoan animals and their remains was noted in the food of oysters by Lotsy (1893) and Korringa (1952). In the Pulicat lake, the animal matter constitutes 1.5 percent, contributed mainly by the veligers and the ciliate, Tintinnopsis.

From the present study it is clear that the oysters feed on diatoms, detritus and animal matter. The major food component being diatoms, they should be responsible for the storage of nutrients and their supply to the gonad at the time of gamete maturation. The breeding of oysters is usually induced by the high temperature and ample food, as shown for the oyster C. virginica Gmelin (Loosanoff and Davis, 1952). The spawning intensity of the oysters is controlled by the quantity of glycogen, and in turn by the quantity of food ingested by the oysters. If the oysters are poor in storing glycogen due to low intensity of feeding, they usually do not develop good gonads since reserve glycogen is needed for the development of the gonad. From this study it was observed that the fattening of oysters during the month of May is mainly by Nitzschia, Navicula, Peridinium which constitute the major diatoms in the food of oysters.

CHAPER TWO

REPRODUCTIVE CYCLE OF *CRASSOSTREA MADRASENSIS* (PRESTON) IN PULICAT LAKE.

During the past decade, considerable emphasis has been laid on the culture of commercially important bivalves in India. In the culture operations of bivalves, information on seasonal gonadal changes, time of spawning and of setting larvae are essential to find out the best time for laying the cultch to collect the spat.

Although work on the reproduction of Crassostrea madrasensis has been done at several places of India, excepting Hornell (1908, 1910 & 1922), nobody worked on the oysters of the Pulicat lake where the environment is quite different from most other Indian estuaries or backwaters, in being a negative type of estuary where the salinity in the oyster-bed area shows very wide fluctuations from 0.37‰ to 39.24‰. Rao (1956) studied the seasonal gonadal changes in the adult backwater oyster C. madrasensis from Ennur, near

Madras. Rajapandian and Rajan (1980) studied the gonadal maturity and spawning of this species in the Tuticorin Bay. Stephen(1980) studied the seasonal gonadal changes in the same oyster from the Mulki estuary, on the west coast of India.

The present study which started in July 1980, covers the breeding cycle of C. madrasensis from the Pulicat lake for a period of two years, from July 1980 to June 1982. The objective of this work is to elucidate the seasonal gonadal changes and spawning in this species which is one of the most common and commercially important bivalves from this lake. The natural oyster-beds of the Pulicat lake are situated at a distance of 4 km from the mouth of the lake and are subject to very wide fluctuations in the environmental conditions such as supersalinity or exposure in summer, floods and silting in monsoon season and tidal influence during the period when the lake is in communication with the sea.

MATERIAL AND METHODS

The material for the present study was collected at fortnightly intervals from the natural oyster-beds at Pulicat. Salinity, temperature and oxygen in the bed area were recorded for the entire period, at 7 A.M. everyday regularly. The collected oysters were cleaned with a fibre brush to remove the epifauna and epiflora. No selection

was made with regard to size while picking oysters from the bed, but in general the smaller ones could not be collected, since the left valve of the oyster was firmly attached to the substratum, and as a result it breaks while removing them with a scrapper. This tends however to exclude the oysters less than 30 mm long in the sample, but some small oysters (spat) below the size of 30 mm could be collected and their gonadal condition could be noted.

Oysters from the natural bed were taken to the field laboratory at Pulicat, linear measurements and weight of the whole oyster were taken. The oysters were shucked and the tissue removed was cleaned in fresh sea water and then the meat weight was taken separately. The mantle tissue was gently lifted up and by using a narrow-mouthed pippette the gonad was gently punctured and the gonadal tissue removed just above the heart and below the hepato-pancreas region and was studied alive under the microscope. The gonads of some oysters were fixed in alcoholic Bouin's solution overnight and microstome sections were taken.

Though the observations were made once in a fort-night during this study, the data was pooled to represent monthly observation.

OBSERVATIONS

Totally 4048 oysters in live condition were examined during the period between July 1980 and June 1982 and their percentage frequency is given in Fig.6 and Table 7. The gonadal smear was prepared and studied under the microscope. The gonad of the oysters when fully ripe covers the hepatopancreas completely and also fills up a considerable area around the viscera. The gonial cells which are present in the watery medium of the follicles develop into gametes which are found around the walls of the follicle. The follicles which are narrow at the onset of gametogenesis begin to enlarge further simultaneously with the growth of the oocytes. The ova are released into the lumen just before spawning. After the spawning period, as a result of the release of the oocytes, the furthermore contraction of the follicles and thus engulf the unshed ova left over in the lumen. In the meantime connective tissue also fills up the large areas in between the follicles, and the ovary enters the regressive stage.

The maturity of the gonad was assessed by measureing the diameter of the ova in different months(Fig 7). Percentage frequency of the ova diameter of four maturity stages of oysters is given in table 8. The stages of the gonadial activity were reckoned partly following the stages recognised by Tranter (1958) and Dinamani (1974). In the

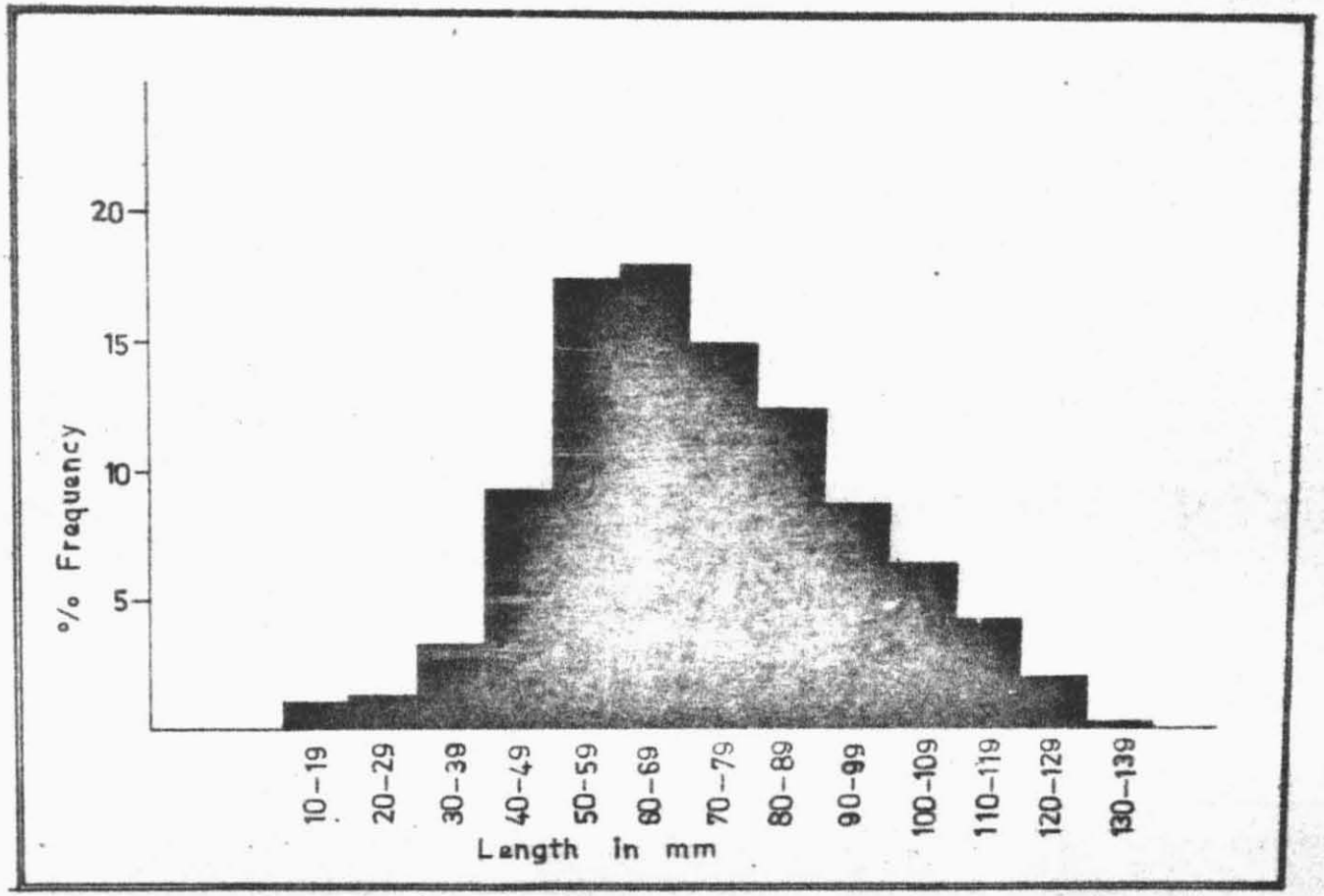


Fig. 6 Size-frequency of oysters examined during the period from July 1980 to June 1982

TABLE - 7

Number of individuals in different size groups of oyster C. Madrasensis

Size Group (m m)	July 1980	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 1981	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 1982	Feb.	Mar.	Apr.	May	June	Total
1-9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	6	16	9	2	37
20-29	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	2	-	2	2	9	3	15	18	-	54
30-39	0	1	1	4	1	10	6	2	3	-	1	2	9	10	2	5	4	9	4	2	8	17	27	14	142
40-49	1	7	9	4	8	34	16	11	20	10	6	10	25	26	6	14	24	10	17	5	21	30	32	28	374
50-59	2	17	3	9	6	26	29	23	27	14	14	31	68	53	17	36	68	45	34	13	50	52	42	29	708
60-69	5	25	17	14	10	12	19	28	18	19	11	27	54	38	27	39	72	62	38	27	38	62	45	24	731
70-79	10	24	12	7	4	15	9	28	20	23	18	31	47	44	17	28	43	28	42	23	33	45	28	28	607
80-89	3	20	13	14	7	18	25	30	32	14	10	20	17	24	17	28	31	13	31	22	32	22	17	17	507
90-99	2	21	13	13	1	21	23	21	29	14	13	14	4	15	11	35	14	17	11	10	23	8	13	8	354
100-109	2	15	8	7	1	12	12	23	17	9	9	3	7	21	10	25	11	19	12	6	10	9	12	5	265
110-119	3	7	8	8	2	2	11	16	8	5	6	8	6	3	10	9	8	12	9	3	13	6	6	6	175
120-129	-	2	2	3	-	3	5	10	13	3	2	3	2	7	2	3	1	5	4	-	6	2	3	4	85
130-139	3	-	1	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	9
140-149	-	-	-	-	-	-	-	-	-	-	-	-	--	--	--	-	-	-	-	-	-	-	-	-	--
	31	139	87	83	40	153	155	192	187	111	90	149	240	244	121	234	276	242	206	122	243	284	254	165	4048

present study the following eight stages were recognised *viz.*, 1,2 and 3 gametogenic phase,4 ripe, 5 partly spent, 6 spent, 7 regressive phase and 8. indeterminate stage.

OOGENESIS

Stage I (Gametogenic) Oogonia very small in size; size of the follicle small; size of the oogonia range from 4 µm to 8µm; during this period the nucleus, nucleoplasm and nucleolus are not distinctly seen.

Stage II (Gametogenic) Oocytes are bigger than the oogonial stages, Nucleus and cytoplasm or ooplasm are distinctly seen. The diameter of the oocytes varies from 24µm to 32µm (Plate 9A).

Stage III (Gametogenic) The nucleus, nucleoplasm and the nucleolus are larger in size. Oocyte is provided with a long stalk which is mainly embedded in the follicular tissue. Oocytes are in the lumen and their size-range is 41 µm to 49µm, and the length of the stalk or peduncle may vary from oocyte to oocyte, and within the same gonad, in different areas. The maximum length of the stalk noted was 98 µm. The shape of the peduncle is broader at the base of the oocyte and stumpy or pointed at the tip. The width is 25 µm at the base of the

Table.

Percentage frequency of the ova diameter of four maturation stages of the oyster, C. madrasensis.

Size of ova (µm)	Maturity stages (%.) I	II	III	IV
4	41.04	--	--	--
8	32.05	--	--	--
12	15.38	--	--	--
16	8.97	--	--	--
20	2.56	--	--	--
24	--	31.17	--	--
32	--	46.75	--	--
41	--	1.30	24.41	--
49	--	3.90	45.67	12.70
55	--	--	18.11	26.98
66	--	15.58	11.81	38.10
74	--	--	--	22.22
82	--	1.30	--	--
Number of oysters examined in each stage	16	24	47	21

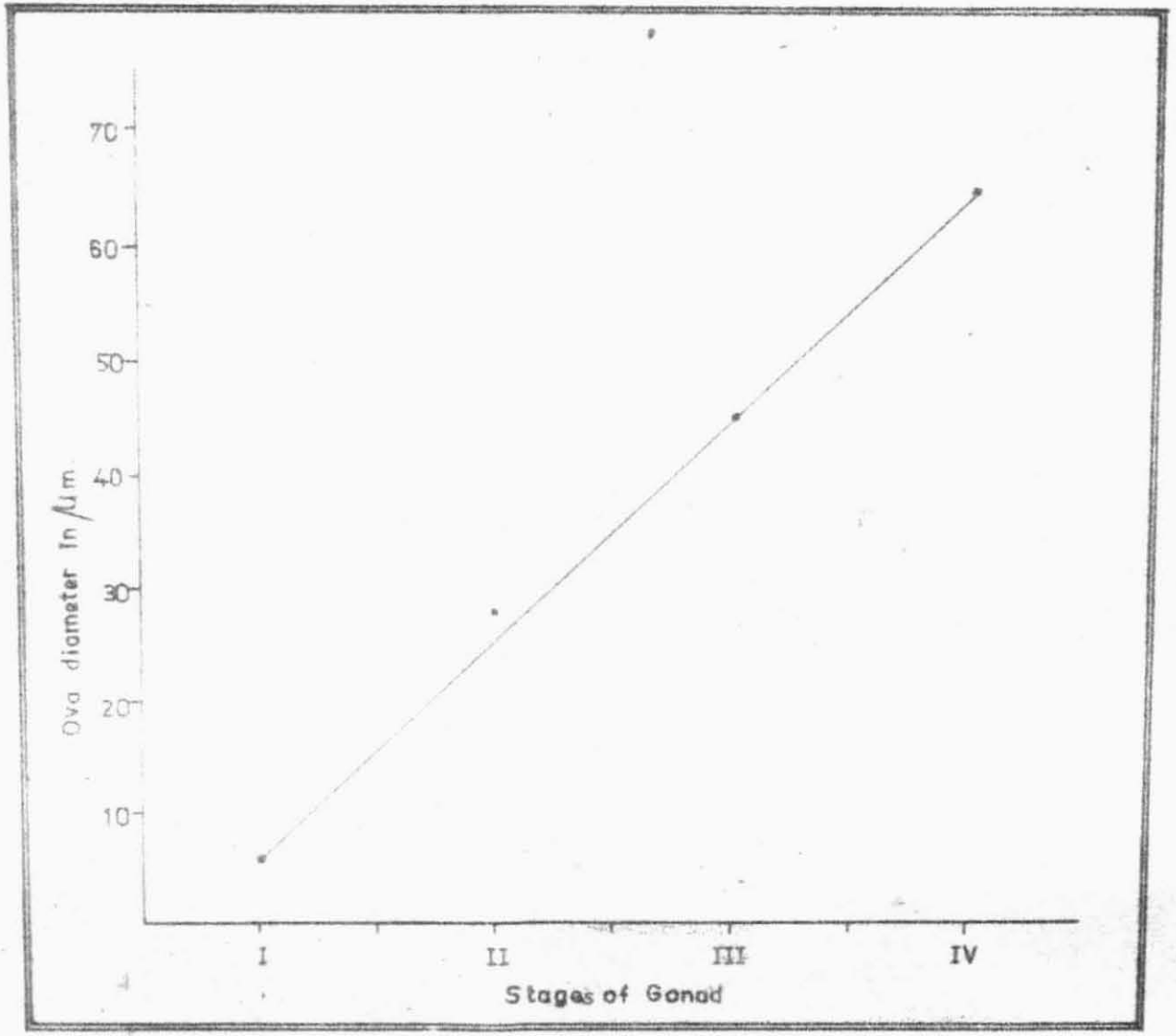


Fig. 7 Ova diameter observed during the four different maturation stages of the oyster C. madrasensis (Modal values of ova diameter measurements of the oysters in samples examined - data pooled after examination of individual oysters).

ova and 8 µm or even less at the tip of the peduncle. The size of the nucleus ranges between 25 µm and 33 µm (Plate 9B).

Stage IV (Ripe) — Ova are large, rounded and the stalk is completely constricted and in some cases the stalk is very much reduced in size. Ova are free in the lumen. Follicles occupy the entire area of the gonad with little or no interfollicular tissue. The diameter of the fully matured ova ranges between 55 µm and 74 µm. Follicles are full of ripe ova (Plate 9C).

Stage V (Partially spent) — There are a few numbers of ova in the follicular lumen. This stage usually occurs during the peak period of spawning(Plate 9D).

Stage VI (Spent) — The follicles are empty without any ova, or sometimes one or two occasional ova in the gonad. Phagocytes make their occurrence alongwith unspawned gonial cells. This is the period of static condition or inactive phase (Plate 9F).

Stage VII (Regressive) — After spawning is over, follicles contract further and enclose the free unshed oocytes. Connective tissue is present in between the follicles and grows further and thereafter

LEGEND FOR PLATE - 9

FEMALE

A- Stage II. Showing growth of oocytes.

B- Stage III. Showing the oocytes attached to the follicular walls by stalk-like connection.

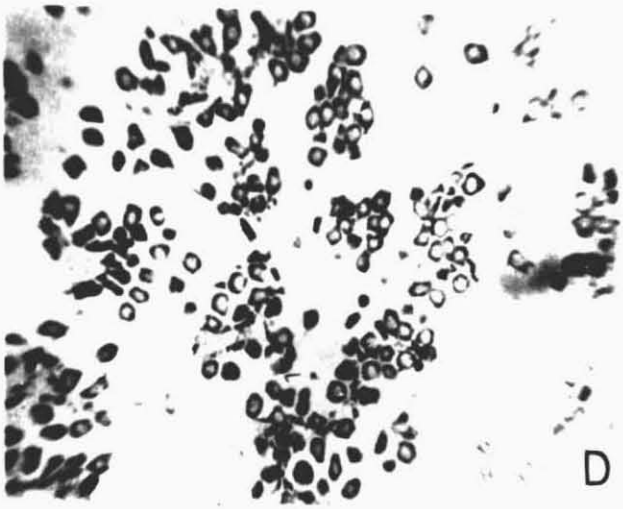
C- Stage IV. Fully ripe ovary with rounded free oocytes.

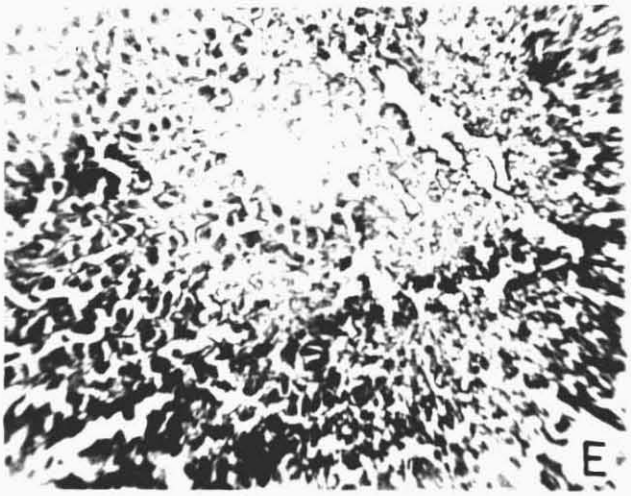
D- Stage V. Partly spent gonad with few oocytes on follicular walls.

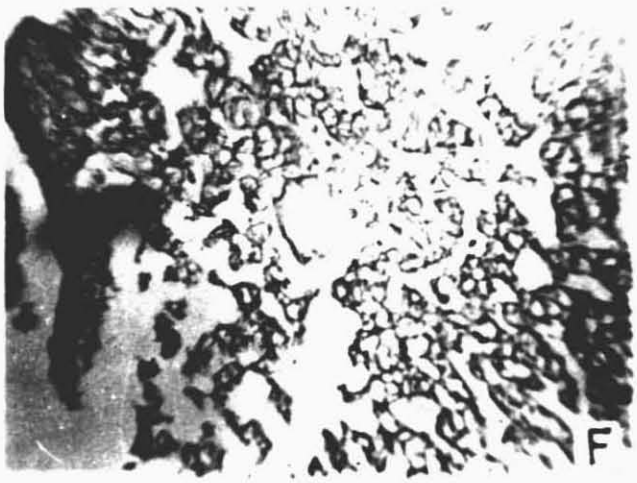
E- Stage VII. Regressive ovary with shrunken follicles containing some ova covered by connective tissue.

F- Stage VI. Showing the spent ovary.

PLATE 9







the ova enter into the regressive phase.

Resorption or cytolysis : Ova reduced in size, nucleus not distinct, follicular tissue slowly disappears. In most of the cases ova are transparent, irregular, polygonal and even the nucleus is not rounded. The inner contents of the ova are released during this stage. The cytoplasmic layer is very transparent and no cell granules are found to occur. At the same time the nuclear portion, after disintegration, by oozing out the granular material is being phagocytosed (Plate 9E).

Stage VIII (Indeterminate) After completion of spawning, follicles are empty and are with phagocytic cells inside the lumina. The follicles are completely obliterated. The vesicular connective tissue also shrunken, very thin, and studded with phagocytic cells. The sexes at this stage become indistinguishable. The oyster is now at an indifferent stage.

SPERMATOGENESIS

Stage I The spermatogonial stages between the primordial germ cells and the definitive spermatogonia show a considerable decrease in size and cytoplasmic volume. The spermato-

gonia are easily recognised by their large nuclei and thin clear cytoplasmic envelopes.

Stage II — The spermatogonia give rise to primary spermatocytes which are free with a large rounded nucleus and a thin cytoplasmic layer(Plate 10A).

Stage III — The secondary spermatocytes are formed inside the primary spermatocytes. These cells are smaller in size and distinguished by their small and dark nuclei (Plate 10B).

Stage IV — As the gonad attains ripe condition the spermatids differentiate into spermatozoa which lie as a core in the lumen of the follicle. The spermatozoa are very active and are found in streams. There is a corresponding decrease in the volume of the other earlier stages of cells. Ripe gonads are characterised by a stream of spermatozoa, with tails directed into the lumen which occupy a large area of the follicle (Plate 10C).

Stage V — Gonads of the oyster which are partially spent are characterised by the partial shrinkage of the follicles and with the central part of the lumen in the male rarely full. The sperms occur as small scattered patches (Plate 10 D).

LEGEND FOR PLATE 10

MALE

A- Stage II. Showing the secondary spermatocytes.

B- Stage III. Showing the spermatids in follicles.

C- Stage IV. Showing the fully ripe testis with streams of spermatozoa in follicles.

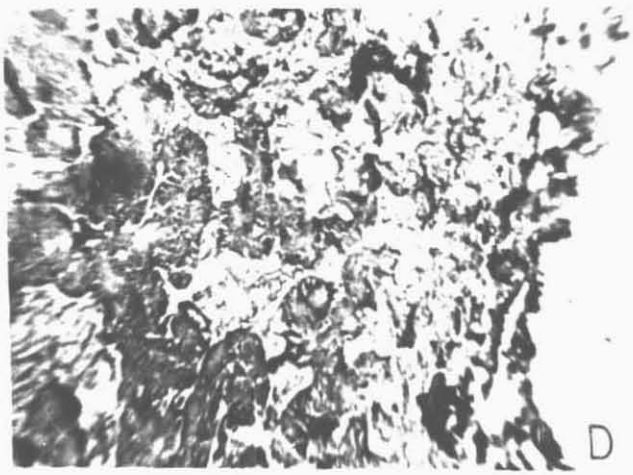
D- Stage V. Showing the partly spent tentis with distrupted follicle.

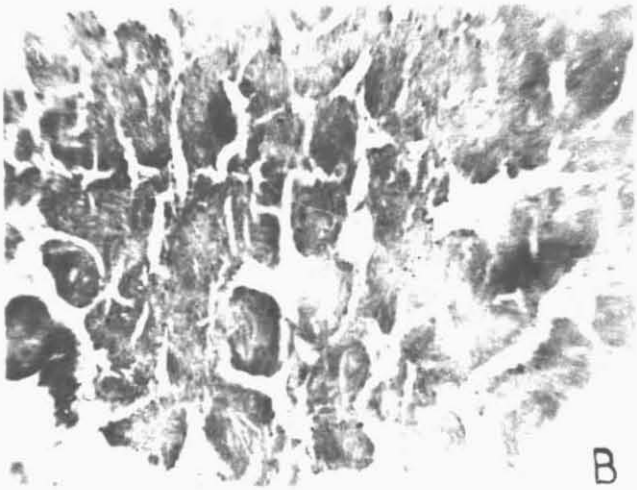
E- Stage VI. Fully spent gonad with completely disrupted follicle.

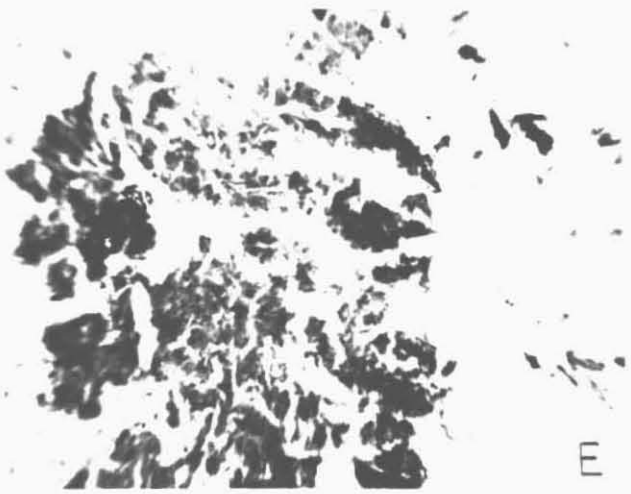
F- Stage VII. Showing regressive testis with contracted follicles.

PLATE 10

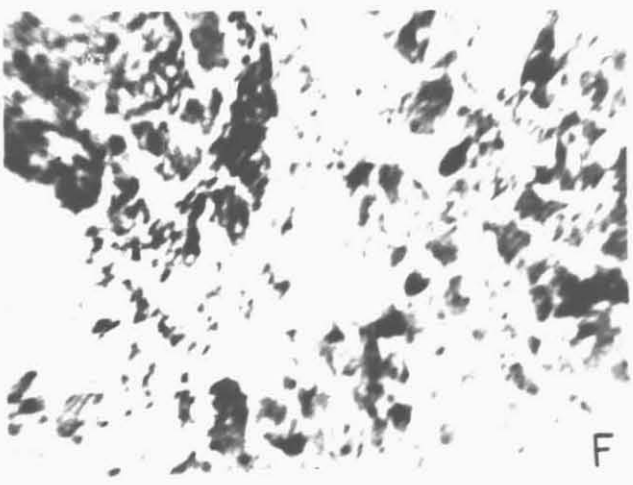

A


D


B


E


C


F

Stage VI — During this stage the follicles are devoid of spermatozoa. However, sex can be determined by locating remnant sperms in the gonad. The vesicular connective tissue also increases in volume. The presence of enormous phagocytic cells in the interfollicular space is noteworthy (Plate 10 E).

Stage VII — The lumina of the follicles contain residual spermatozoa in a state ready for cytolysis or absorption. The gonad undergoes the regressive phase and there is no proliferation of germ cells. The empty follicles and many phagocytic cells inside the lumina are completely obliterated. The sexes at this stage become indistinguishable, gradually turning flabby and the indistinguishable stage is a resting phase for a short period (Plate 10 F).

GONADIAL CYCLE

FEMALE : The process of gametogenesis involves formation, multiplication and differentiation of the reproductive cells, mobilisation of nourishment, gamete accumulation and discharge. The gonads of C. madrasensis originate from a group of mesodermal cells located in the posterior portion of the body near the visceral ganglion and ventral to the pericardium.

At first, the primary germ cells(oogonia) undergo mitotic division and give rise to many more oogonia, in the early phase of oogenesis.

The ovarian part of the gonad of the oyster showed gametogenic activity throughout the period of this study except in the month of November '80 and April, May 1981. As a result, ripe gonads occurred in all the months, during the two years of observation. The month-wise stages of gonad and their percentages are given in Table 9. Seasonal gonadal changes of females are given in Fig 8 and Table 10.

Maximum number of oysters with gametogenic activity was noticed during July and August 1980 and the percentages in the two months were 66.7 and 70.7 respectively. The oocytes grow further in size and the ripe ones seem to occur in high percentages during September and October 1980. As a result, the oocytes attached to the follicular wall were released into the lumen and they were found fully grown in size. The third stage of oocyte is large and irregular in shape and with a slender stalk embedded into the follicular wall. The diameter of the oocyte is 41 µm. The cytoplasm is clear, distinct, the nucleus well developed and with a diameter of 33 µm. The stalk or peduncle is broader at the base of the oocyte where it is connected to the oocyte but the other end is pointed

TABLE .9

Percentage frequency of gonadal phases in the population of C. Madrasensis

Stages of Gonad	Month and Year																						
	July 1980	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 1981	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 1982	Feb.	Mar.	Apr.	May	June
Gameto-genesis	54.84	69.06	43.68	24.10	--	1.31	0.65	22.92	12.90	--	--	11.41	28.33	59.84	28.10	9.40	2.54	8.30	11.76	23.7	25.69	34.51	0.82	2.80
Ripe.	9.68	1.51	36.76	71.08	75	18.30	7.10	16.15	51.08	47.74	21.11	11.41	16.67	11.48	39.66	54.76	22.10	8.30	14.71	10.66	24.31	54.58	32.10	28.97
Spent	3.23	1.45	--	1.20	25	68.63	53.55	33.33	29.57	41.44	66.00	43.62	22.92	19.67	15.70	26.50	61.98	65.56	44.12	18.85	8.26	7.04	61.73	25.23
Regressive	12.90	9.35	14.94	1.20	--	7.84	34.84	21.88	--	--	13.33	24.83	25.00	5.74	10.74	--	--	8.71	23.04	27.05	33.94	1.76	1.65	38.32
Indeter-minate	19.35	8.63	4.60	2.41	--	3.92	3.87	5.73	6.45	10.81	5.56	8.72	7.08	3.78	5.79	9.40	13.41	9.13	6.37	19.67	7.80	2.11	3.70	4.67

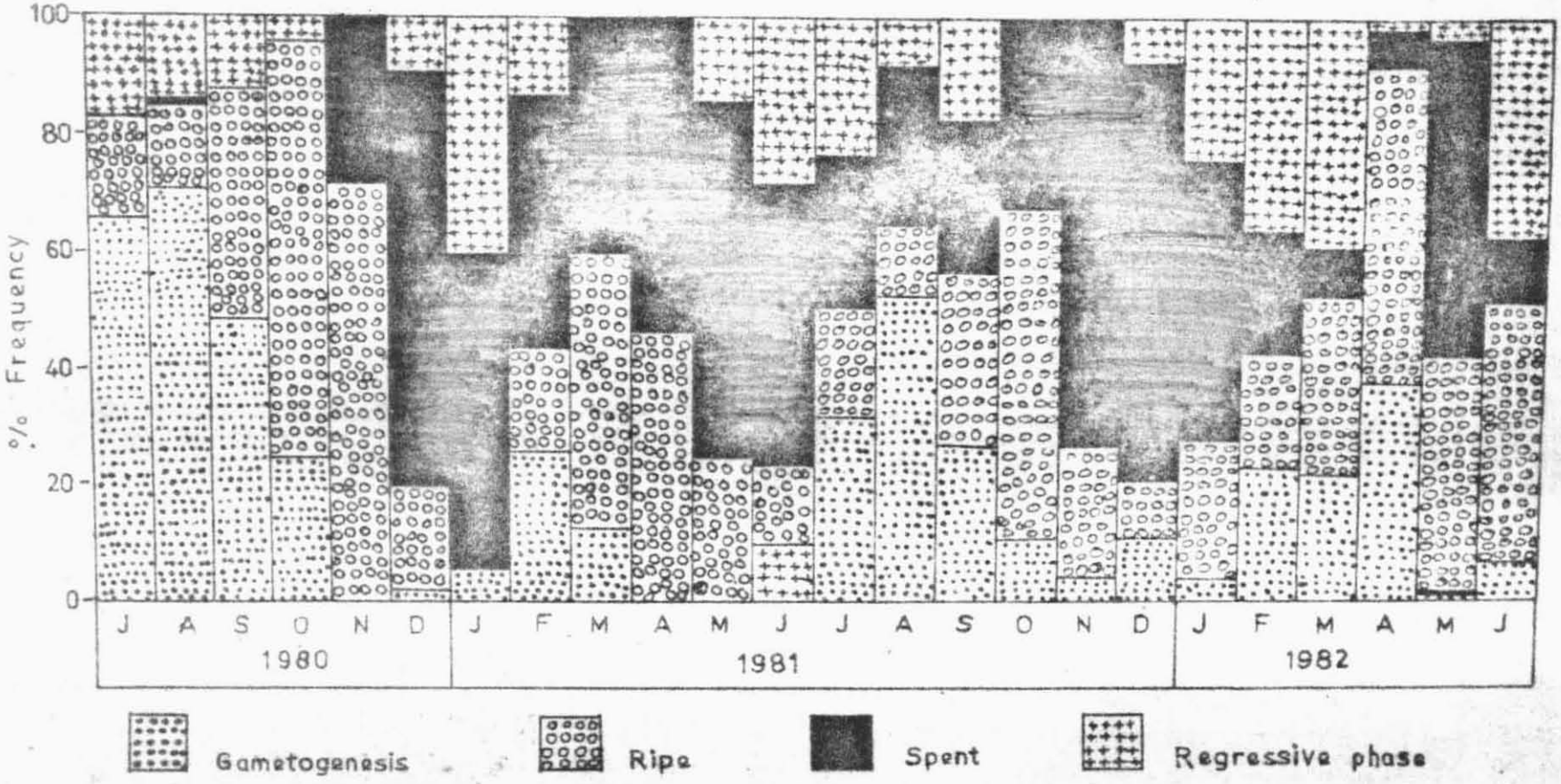


Fig. 8 Frequency of the female gonadal phases in the monthly samples of the Indian edible oyster, C. madrasensis from the Pulicat lake

or sometimes blunt for attachment to the follicular wall. With the growth of the oocyte, the stalk is reduced in size considerably and the oocyte becomes rounded with a diameter ranging from 49 to 55 µm, when they are released into the lumen. At this stage, the cytoplasm and nucleus in the oocyte increases in size. The majority of gametes are in the ripe condition filling the enlarged follicles during the months of October and November 1980.

The maximum number of oysters with ripe ova were noticed during October and November '80 and their percentages were 70.45 and 72 respectively. The percentage of ripe ones had fallen suddenly during the first half of December '80 indicating the spawning of oysters as evidenced by the occurrence of numerous spent and partially spent oysters in the population. The gonadial follicles had shrunken to a large extent and vesicular tissue surrounding the ova and connective tissue cells also were scattered everywhere. Samples collected immediately after the monsoon had shown increasing numbers of spent ones and during this period the gonads were flimsy, transparent, thin and also loose in consistency. In the advanced stage of spawning, the lumina of the follicles contain a few relict ova. The follicles contract further and close the unshed oocytes. The gonadial follicles are invaded by a number of phagocytes. In the meantime, the connective tissue fills up the inter-follicular areas and the ovary

TABLE - 10

Percentage frequency of gonadial phases in the Monthly samples of C. madrasensis from the Pulicat lake.

Sex	Month and Year																						
Females	July 1980	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 1961	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 1982	Feb.	Mar.	Apr.	May.	June
I	33.33	3.66	--	--	--	--	--	3.79	1.75	--	--	10.23	6.98	9.23	3.18	--	0.74	10.57	--	--	7.76	--	--	3.45
II	22.22	41.46	9.30	--	--	--	--	11.36	3.51	--	--	--	6-20	3-85	4-76	--	--	--	3.85	15.91	6.03	--	--	--
III	11.11	25.61	39.53	25.0	--	2.06	1.21	10.61	7.89	--	--	--	18.60	40.0	19.05	11.34	2.96	--	--	6.82	7.76	38.41	1.83	3.45
IV	16.67	14.63	39.53	70.45	72.00	17.53	4.82	18.18	46.49	46.67	25.40	13.64	19.38	11.54	30.16	56.70	22.70	9.76	24.04	20.45	31.03	53.62	41.28	44.83
V	--	--	--	2.27	28.00	17.53	6.02	6.82	22.81	38.33	22.22	5.68	6.20	1.54	--	13.40	2.22	8.94	17.31	[illegible]	[illegible]	--	29.36	--
VI	--	1.22	--	--	--	54.64	48.19	31.82	17.54	15.00	38.10	42.05	19.38	26.15	25.40	18.56	70.37	63.41	30.77	20.45	7.76	6.52	24.77	10.34
VII	16.67	31.41	11.63	--	--	8.25	39.76	17.42	--	--	14.29	28.41	23.26	7.69	17.46	--	--	7.32	24.04	36.36	39.66	1.45	2.75	37.93
Males																								
I	57.14	--	--	--	--	--	--	12.24	--	--	--	10.42	10.64	0.94	--	--	--	4.17	14.94	--	12.73	--	--	9.48
II	14.29	46.67	--	2.70	--	--	--	4.08	8.33	--	--	4.16	10.64	19.81	7.84	--	0.96	--	[illegible]	18.52	[illegible]	--	--	1.23
III	--	37.78	42.50	21.62	--	--	--	4.08	6.67	--	--	2.08	7.45	50.00	25.49	9.57	0.96	3.13	3.45	16.67	13.64	12.14	..	--
IV	--	8.89	37.50	75.68	80.00	22.00	10.61	14.28	70.00	64.10	13.64	10.42	15.96	12.26	56.86	63.48	27.88	8.33	3.75	7.41	15.45	57.86	29.45	22.22
V	14.29	2.22	--	--	26.00	12.10	10.61	12.24	5.00	20.50	13.64	6.25	7.45	0.94	1.96	14.78	16.35	28.13	11.49	--	--	--	14.25	--
VI	--	--	--	--	--	58.00	56.06	14.28	10.00	15.38	59.09	41.67	15.96	12.26	3.92	12.17	53.85	43.75	34.48	25.93	8.15	7.86	28.08	29.63
VII	14.29	4.44	20	--	--	8.00	31.82	38.78	--	--	13.64	25.00	31.91	3.77	3.92	--	--	12.5	25.29	31.48	25.[illegible]	22.14	1.37	37.04

is in the regressive phase. As a result of the disintegration and cytolysis of the unspawned reproductive elements 22.2% of the spent female oysters were found with the invasion of phagocytes both inside and outside the follicles. This has been interpreted by various workers (Cole, 1942; Rao, 1956; Millar,1964; Durve, 1964) that the phagocytic cells devour and grow at the expense of the residual reproductive elements and the significance of the process is probably to clear the gonad before the next period of gametogenesis. It is at this stage, the sex of the individual is indeterminate. The empty follicles are shrunken and elongate and come into close contact with the digestive gland. Majority of oysters entered this indeterminate stage during January and June of both the years of study.

The percentage of regressive and indeterminate oysters was high during January, immediately after the spawning was over. The unshed ova in the lumen of the follicles were resorbed during this period. The vesicular connective tissue was very thin and studded with the phagocytic cells. This is the period of recovery, and the sexes at this time become indistinguishable. The percentage of recovery was maximum in January. All the spent ones recover for the next breeding season. During February and March '81 again, in most of the individuals gametogenesis was found to recur and the mature or ripe female

gonads were found to occur in April. This is the second phase of the annual cycle during which very rapid proliferation of oogonia commenced. Ripe oysters were found more during the month of April. During May, the ripe gametes decline considerably indicating the completion of the second peak of spawning during April.

MALE : The gonad of males was studied both by the Smear Method and through histological sections. The stages of the gonad were ascertained by the size and development of the gametes. The month-wise percentages of gonadal stages occurring during the spermatogenesis are given in Fig 9 and Table 10.

The primordial germ cells, after a series of divisions, give rise to spermatogonia. The spermatogonia are easily recognised by their large nuclei and thin, clear cytoplasmic envelopes. They are usually found attached to the follicular wall during July and August 1980. The activity of the gonad was considerably high during this period and spermatogonia undergo furthermore divisions to give rise to spermatocytes which lie as a core in the lumen of the follicles. As the gonad attains maturity the spermatozoa are very active and are found in streams. There is a corresponding decrease in the volume of the cells compared to the earlier stages. Ripe gonads are characterised by streams of spermatozoa, with thin tails

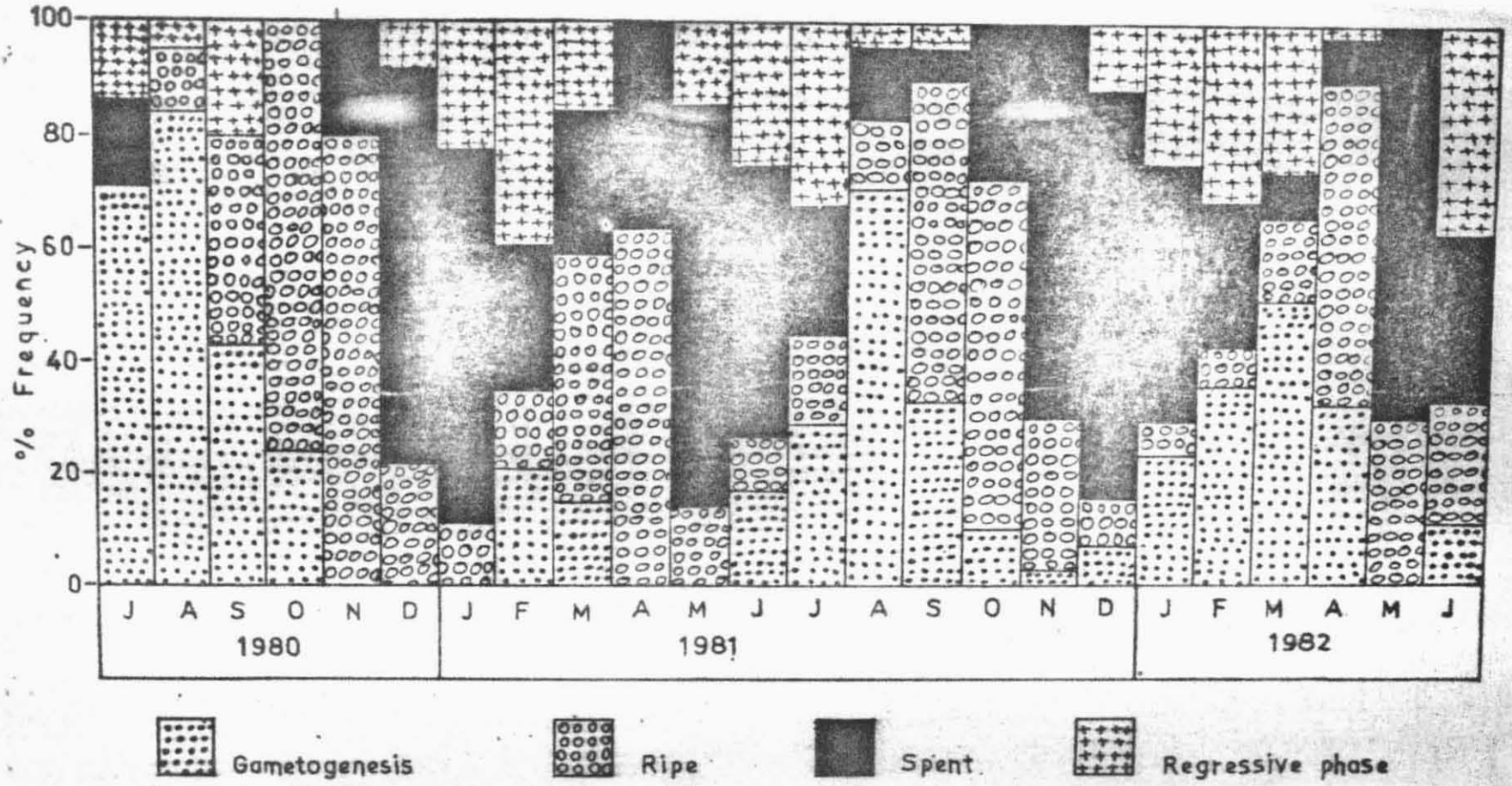


Fig. 9 Frequency of the male gonadal phases in the monthly samples of the Indian edible oyster, C. madrasensis from the Pulicat lake.

directed into the lumen and occupying a large area of the follicle. Onset of spawning was observed during the beginning of the second half of November following heavy floods in the lake due to the North East Monsoon. The percentage of ripe ones decreased considerably towards the end of the second half of December.

Soon after spawning is over, in some oysters, spermatozoa occur in small patches distributed in the gonad. In the spent male oysters, follicles seem to be shrunken to a great extent. The vesicular connective tissue also increases in volume. The invasion of the phagocytes into the interfollicular spaces was noticeable. The oysters which attained maturity late, or are unspawned or partly spawned showed spermatozoa in the follicles that were being cytolysed or absorbed. The gonad undergoes regressive phase and there was no proliferation of germ cells. The empty follicles and many phagocytes inside the lumina are completely obliterated. The sexes at this stage become indistinguishable, the gonads gradually turning flabby as in females. The spent and indistinguishable gonads are in the resting phase for a short period when there is a shortage of reserve materials in the gonads. The next season of spermatogenesis is indicated by a great increase in the spermatogonia and by a decrease in phagocytic activity. The same pattern of gonadial cycle was repeated in the following year also.

REPRODUCTIVE CYCLE

Annual reproductive cycle of Crassostrea madrasensis is studied here for a period of two years by obtaining fortnightly samples and by studying stages of maturity as described earlier. The month-wise stages of gonads and their percentages are given in Table 9 & Fig 10. The seasonal changes of gonad occurring in the population for the period from July 1980 to 1982 are given in Fig 10. The stages I, II, and III were grouped as one, which are mainly concerned with gametogenesis or otherwise called as the 'Active phase'. The IV stage is the 'ripe' condition wherein the gametes are ready to be released. The V stage is the partly spent and VI stage is 'inactive phase' implying a static condition where absolutely no morphological or biochemical activity is taking place. After spawning, follicles contract further and enclose the free and unshed oocytes. Connective tissue fills up the large areas between follicles and the ovary undergoes a 'regressive phase', where the gonad shows no signs of sex or the speciments cannot be sexually differentiated, implying low levels of spermiogenic or ovogenic activities. The month-wise percentages of each stage for the period from July '80 to June '82 are given in Table 7, and the gonadal changes of the oysters are described under the four seasons.

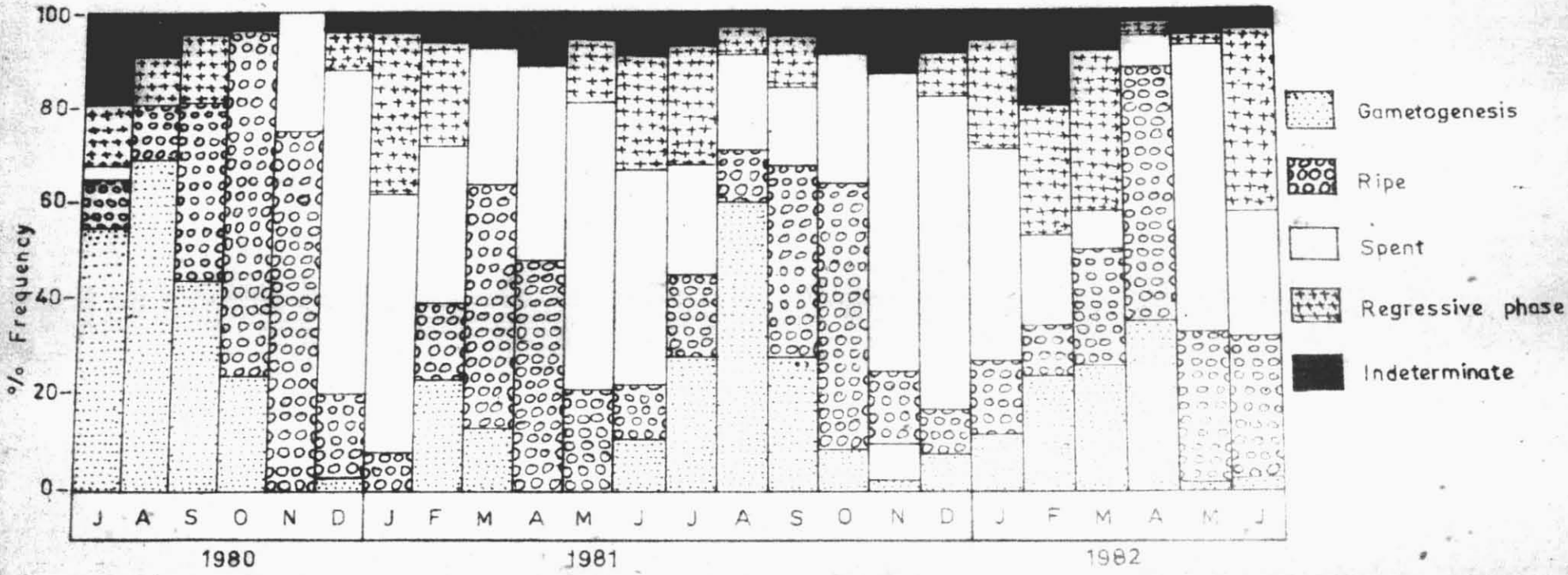


Fig. 10 Seasonal gonadal phases in the monthly samples of the population of *C. madrasensis* from the Pulicat lake.

PRE-MONSOON

July 1980

During the month of July '80, most of the oysters were in the 'active phase' showing the early gametogenic stages. A few of the oysters were in the regressive condition undergoing cytolysis due to unfavourable conditions for spawning. The percentage frequency of gametogenic phases were 66.67 and 71.43 during this month, in females and males respectively. Among the three phases, phase-I seems to dominate in most of the oysters and their percentages in both females and males were 33.33 and 57.14 respectively.

AUGUST

The gametogenic activity initiated during the month of July becomes vigorous and grows further, as a result of which the percentage of oysters in this gametogenic phase increases to 70.73 and 84.45 in females and males respectively. In both the sexes, the IInd stage of the gonad dominated and their percentages were 41.46 and 46.67 in females and males respectively. The gonadal follicles and ductules closer to the periphery contained large, ripe ova, oogonia and developing oocytes near the germinal epithelium. The germinal epithelium was actively proliferating fresh oogonia in all the follicles. The lumina were almost packed with spermatocytes. The residual oocytes and spermatocytes which were present in some of the oysters undergo cytolysis.

SEPTEMBER

Change of the gametogenic phase into the ripening phase starts during this month. As a result of the rapid growth of gonadal follicles the percentage of individuals with gametogenic activity decreases to 48.83 and 42.5 in females and males respectively; on the otherhand ripe ones increase to 39.53% in females and 37.5% in males. In this active phase, 39.53% and 42.5 % of female and male oysters were found in the third phase, and the other stages were considerably less. During this period the oocytes were found with long peduncle or stalks which were mainly embedded in the follicular tissue. The gonadal follicles became broader and bear both female and male gametes. The III and IVth stages of gametes are found equally distributed in the gonads of both the sexes during this month.

MONSOON

OCTOBER 1980

A few of the oysters were in the gametogenic activity, whereas a majority of the oysters were found in the 'ripe' condition. The percentage of ripe gonads in both males and females were 75.68 and 70.45 respectively. During this period the gonads of both the male and female oysters were full. The follicles were enlarged and packed with ripe reproductive elements. The inter-follicular vesicular tissue as well as the connective tissue between

the gonadial layer and the gut were reduced to the minimum level. Even though the majority of oysters were in the ripe condition, almost 25% of the males and females were still advancing towards the ripe stage. During this period the gonads have become full and plumpy and form a major bulk of the viscera, as a result of which the external surface was flabby and smooth. No spent or regressive individuals were found during this period.

NOVEMBER

The percentage of ripe oysters increased furthermore to 72 and 80 in females and males respectively. In the meantime, 28% and 20% of the females and males were in the partially spent condition. Since the North East monsoon started during the middle of November, with heavy rains on the lake, there was a sudden fall of salinity to 0.37‰which triggered off the oysters to spawn at this moment. The gonads gradually turning flabby and slightly transparent and showing a creamy coloured patch of granules indicated that the spawning has already started. Later, the follicles get shrunken, and also there was a reduction in the number of gametes present in the lumen. The ova in the lumen of the follicle were few and small in size and make their appearance near the follicular wall. Thus in November, a few of the gonads were in the partially spent condition.

DECEMBER

Spawning reached its peak during the first half of December '80 and this was indicated by the sudden fall of ripe oysters of both sexes. The ripe oysters which formed 72% and 80% in females and males declined to 17.53% and 22% respectively. Samples collected during this month showed that the partially and fully spent oysters increased steadily compared to the previous month. The percentage of spent females and males was 54.64 and 58 and that of partially spawned ones was 17.5 and 12 respectively. The fully spent ones are characterised by the presence of a negligible number of residual gametes and greater amount of vesicular tissue and condensed connective tissue. Among the spent females 22.22% of the oysters have been found with the invasion of phagocytes both inside and outside the follicles. It was described by various workers, viz., Rao (1956), Millar (1964), Durve (1964), Alagarswami (1966) and Dinamani (1974) that they devour at the expense of the residual reproductive elements and the significance of this process is probably to clear the gonad before the next period of gametogenesis. Another view regarding the function of phagocytic cells is that they contribute nutrients to the sex cells, during active gametogenesis and also resorb residual cells in the spent follicles, (Loosanoff, 1937a, b; Tranter, 1958d; Wilson and Hodgkin, 1967). During this period, the sex

of the individual is indeterminate. The empty follicles are shrunken and elongate and they come into close contact with the digestive gland. Majority of the oysters enter this indeterminate stage during the month of December.

POST-MONSOON

JANUARY 1981

In January, majority of the population was found in the 'inactive' or in the 'indifferent' stage. The follicles have been completely disrupted leaving a hieroglyphic appearance. However, a considerable number of oysters were in the regressive condition. In this case the gametes which were not released undergo resorption by being enveloped with connective tissue around the follicles. During this time, the nucleus disappears, the cytoplasm oozes out and thus the ova disintegrate becoming transparent, and the constituents of the gametes are resorbed completely. When the process of cytolysis and resorption is over the gonads enter the spent and resting phase and the sex of the individual becomes indeterminable. The spent gonads become translucent. Some of the oysters were found in the 'inactive' phase during this stage.

FEBRUARY

After a short duration of resting stage, gametogenesis again started during this period, but the intensity

and the percentage of activity was considerably less when compared to the peak period of activity. The percentage of oysters showing the gametogenic activity in both females and males was upto 25.76 and 20.4 respectively. The sexually inactive oysters were less common compared to the previous month.

MARCH

The percentage of maturing stages decreased to 13.15 and 15 in both female and male oysters respectively, and the ripe ones of the two sexes increased to 46.49% and 70%. The gametogenic activity of males increases considerably higher than that of the females, during this season, showing the advancement of reproductive cycle.

SUMMER

APRIL 1981

The gametogenic activity was completely stopped during this month. The percentage of ripe females and males was 46.67 and 64.10. During the second half of April, spawning has taken place mostly induced by the rise of temperature in the environment and this is evident by the fall in the percentage of ripe males in the population.

MAY

Spawning is vigorous during the first half of may and as a result of this the percentage of spent ones

in the population increases. During the middle of May there is a higher percentage of oysters in the partially spent or'fully spent' phase. Phagocytes make their appearance soon after spawning. A few oysters were noticed undergoing the cytolysis or regressive changes.

JUNE

Most of the oysters were in 'indifferent' and 'inactive' phase during this period and 28.41% of females and 25 %of males were found in the regressive condition, by establishing connective tissue in between the follicles. Onset of gametogenesis was noticed in some oysters during this month.

The same pattern of spawning cycle was observed during the subsequent year, from July 1981 to June 1982, with minor variations in the time and intensity of gametogenesis and spawning. The gametogenic process was very slow in the subsequent year (July '81-June '82). This may be attributed to another reason that the low salinity (24.67‰)due to occasional rains in July had its influence in reducing the gametogenic phase in the subsequent months. Some of the ripe oysters which were not spawned during the summer season were found to spawn in July '81, as a result of occasional rains during that particular month, which shows another traceable peak during the year 1981. From this it is clear, that the ripe ones occur all round the year and spawning takes place whenever there is a

change in the environmental salinity. Majority of the oysters were in the III phase during August '81 whereas in the previous month it was in the II phase. During September '80 there was a considerable delay in the North East monsoon showers and the ripe ones also increased considerably in the population; a similar trend was not seen in September and October '81 when there were rains and as a result the oysters were found in the spawning condition. During the post-spawning months of January, February and March 1982, there was a considerable change in the environment, both in salinity and temperature, and as a result regressive type of gonads were abundant in the population, being 24.04% and 36.36% for females and 25.29% and 31.48% for males for the months of January and February.

Based on these two consecutive years of observations, it was found that the breeding of oysters on the Pulicat Lake is influenced by the North East monsoon which brings down the salinity to lower levels, and there appears to be normally two peak periods of spawning, one in October-November and the other during April-May. The quiscent period for these two peaks was observed during the month of January and June respectively. The gametogenic activity was observed between July and September, and between February and March, in both the years. Congenial salinity for gametogenesis was found to be between 31.06‰ and 36.86‰ in 1980-81 and 34.42‰ to 38.42‰ in 1981-82; and

temperature during that period was 28-29°C in 1980-81 and 27.75°C to 30.25°C during the second year.

SEX RATIO

The ratio of males, females and indeterminate oysters for the entire period of study, from July '80 to June '82, is given in Table .11. The samples analysed for the period from July '80 to September '81 have shown that the females outnumbered the males, with the maximum peaks during November, December '80 and February, March and May 1981. During the period of November and December '80 there was a very active breeding and the percentage of females was considerably high. This percentage of females decreased during January '81, immediately after the breeding season was over, but was considerably high during the month of February as the oysters were found at the onset of gametogenesis. In October 1981, the males outnumbered the females considerably. During this period, spawning has taken place as a result most of the oysters were in the spent condition. Immediately after spawning, particularly during November and December '81 and January '82, the ratio of males and females was almost equal. During February '82 females decreased suddenly to 36.07%, compared to 50.98% for the previous month. The percentage of indeterminate oysters was 19.67 which was found to be high when compared to the other months. This is mainly

TABLE - II

Percentage of Males, Females, Indeterminates and Hermaphrodites

Sex	Month and Year																						
	July 1980	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 1981	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 1982	Feb.	Mar.	Apr.	May	June
Female	51.06	58.99	49.43	53.01	62.5	63.40	53.55	67.71	60.96	54.05	70.00	59.06	53.75	52.45	51.24	41.03	48.91	50.81	50.48	36.07	49.79	48.59	43.08	27.10
Male	22.58	32.37	45.98	44.58	37.5	32.03	42.58	25.52	32.09	35.14	24.44	32.22	39.17	43.03	42.15	49.15	37.68	39.67	42.23	44.26	42.92	49.30	53.36	68.22
Indeterminate	19.35	8.63	4.59	2.41	—	[illegible]	[illegible]	[illegible]	6.42	10.81	5.56	8.72	7.08	3.28	5.79	9.40	13.41	9.09	6.31	19.67	7.10	2.11	3.56	4.67
Hermaphrodite	—	—	—	—	—	0.65	—	[illegible]	[illegible]	—	—	—	—	1.23	0.83	0.43	—	0.41	0.97	—	—	—	—	—	—

due to the sudden increase in salinity in the oyster-bed and due to the lowering of temperature. During this period, the bed was completely exposed, especially during the low tide, and as a result there was the possibility of reduction in the filtration and the consequent paucity of food necessary to change the sex into the male.

The indeterminate oysters were found to occur in the samples throughout the period of study, except during November 1980. The percentage of indeterminate ones was found to be high, immediately after the spawning was over. From the Fig 11, it is very clear that the peak of indeterminates was in July '80, April and November '82. The presence of indeterminate oysters changes the sex-ratio of males and females considerably. During the month of July '80 the percentage of indeterminates was high and as a result the population of males dropped off considerably, such a small peak was found in June and July '81 which reduced the proportion of females to a certain extent. The high percentages of indterminates during April and November '81 reduced the percentage of females during April, and the male population during November '81. In the month of February '82 there was a sudden rise in the percentage frequency of indeterminate oysters which resulted in the sudden fall of females in the population. During this period most of the individuals in the population have undergone

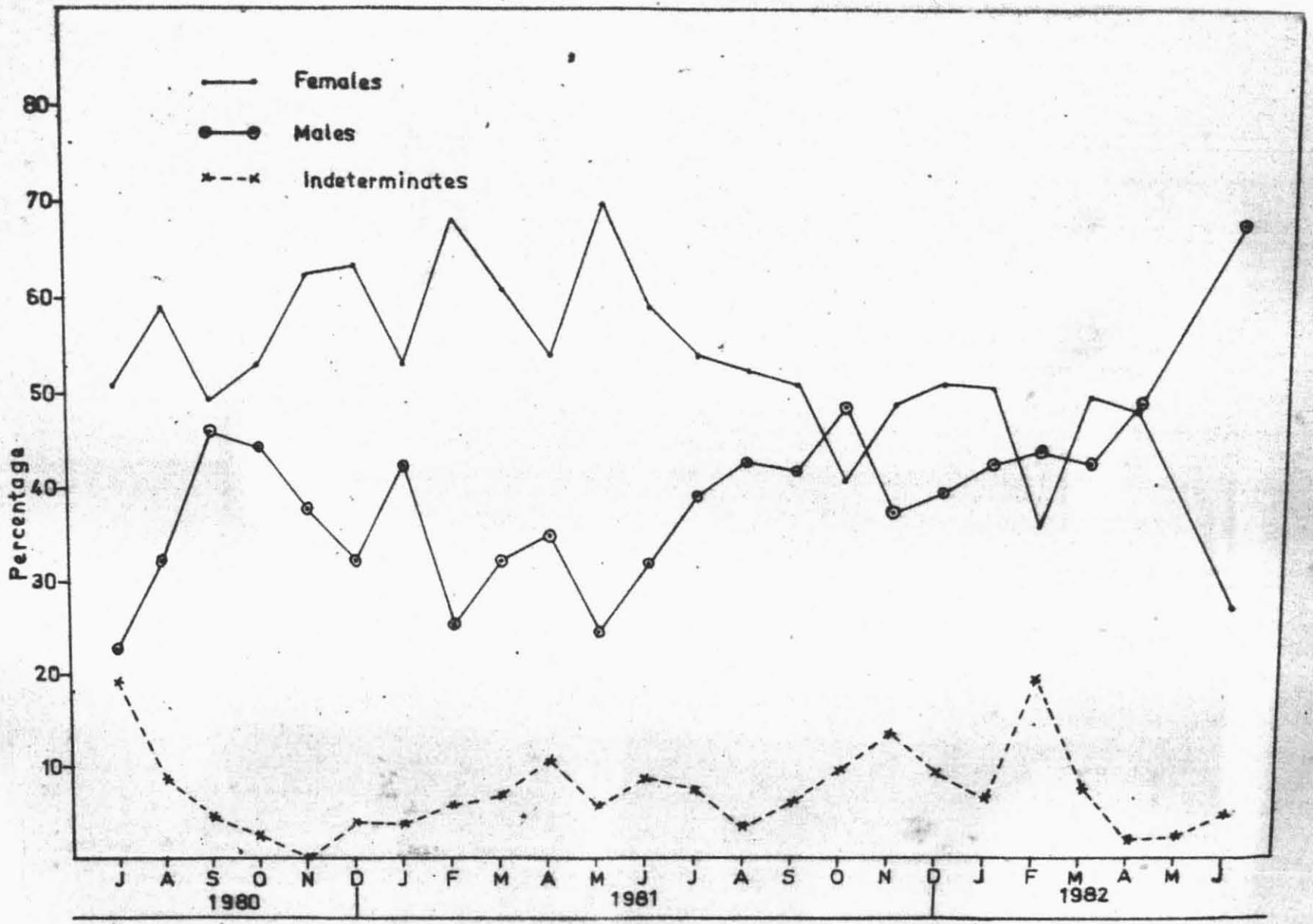


Fig.11 Graph showing the percentages of males, females and indeterminates of C. madrasensis observed from July 1980 to June 1982

regressive stage as a result of exposure during the low-tide and due to the shortage of food for the oysters in the bed. The onset of gametogenesis in few oysters was noted during this period.

Thus the presence of indeterminates and their fluctuations in the population during the period of spawning and post-spawning alters the sex-ratios and consequently it forms the basic reason for the wide fluctuations in the sex-ratio of males and females.

Rao (1956) has mentioned the domination of males in C. madrasensis during the summer season, and females in the pre-monsoon months in the Ennur backwaters. Durve (1964) worked on C. gryphoides and found that the domination of females occurred when there is a fall in salinity and temperature; and that males dominate during September and October when there is a rise in salinity. Oysters growing comparatively under more favourable conditions have a larger proportion of females than males (Coe, 1934, 1936). Throughout the breeding season of O. edulis L., the males always outnumbered those in the female phase (Millar, 1964). Cole (1942) also found a decline in the proportion of females as the summer advanced, but in O. lurida, according to Coe (1932a,b) 'there seems to be no marked tendency for any particular sexual phase to appear at any definite period of the year'. Dinamani (1974) has reported that the percentage

of females was greater especially during the active breeding season and dropped off after the breeding season.

The present investigation has revealed that the abundance of females or males in a population is not only influenced by salinity and temperature, as explained by Durve (1967), but agrees with the views of Coe (1932) also, as mentioned earlier. The co-existence of higher salinity, temperature and shortage of food in the environment for a considerable period of time affected the sex of the oyster population, reducing the number of females and increasing the number of males.

HERMAPHRODITISM

In the Indian oyster, C. madrasensis, hermaphroditism and sex-reversal have been recorded by Rao (1953,1956), Devanesan and Chacko (1955), Rao (1974) and in C. cucullata by Awati and Rai (1931). Asif (1979) studied hermaphroditism in different size groups of C. madrasensis, C. rivularis, C. cucullata and S. glomerata of the Karachi coast. In the present investigation of hermaphroditism, the period of occurrence of hermaphrodites and the probable effect of salinity, temperature and food on sex-reversal are discussed.

Out of the 4048 oysters examined, 12 oysters with hermaphrodite gonads were recorded during the pre-monsoon

and post-monsoon periods, and the data are given in Table 12.

The hermaphrodite individuals which were found during the premonsoon, monsoon and post-monsoon months showed a regular periodicity. In the pre-monsoon period, August, September and October '81, the male characters showed dominance and transition occurs from female to male. Immediately after spawning.,i.e., during the month of December '80 and 1981 males were found dominant and the female gonadial cells were found diminishing. During the post-monsoon season, just prior to spawning in April, hermaphrodites were noted and they were dominated by females which changed their sex for the male phase.

The type of hermaphroditism noted in the Indian species of C. madrasensis is similar to that of the American oyster C. virginica and the Pacific oyster C. gigas and is termed ambisexuality or monoecism with alternative sexuality (Coe, 1943). The adults function either as males or females in any one spawning season and sex changes occur in between two spawning seasons.

Table 12 shows the period of occurrence of hermaphrodites, size and the sexual phase dominant. Usually, in young oysters of the size-range 41-60 mm, the percentage of hermaphrodites is very high (58.33%) as also in the

Table. 12

Hermaphrodites and their dominant sexual characters correlated with Salinity, Temperature and food in the gut of the oyster Crassostrea madrasensis.

Date	Size (mm)	Salinity ‰	Temp °C	Diatoms in the lake	Diatoms in the gut of oyster, etc.	Dominant sex
11.12.80	124	7.61	25.5	high	moderate	male
25.2.81	58	30.82	28.0	poor	poor	male
25.2.81	56	30.82	28.0	poor	poor	male
22.3.81	95	34.62	30.0	poor	moderate	male
14.8.81	69	35.02	29.5	moderate	poor	male
28.8.81	54	38.42	26.0	moderate	moderate	female
28.8.81	47	38.42	26.0	moderate	moderate	female
28.10.81	57	11.78	28.8	high	high	female
13.12.81	46	9.04	25.0	high	poor	male
23.1.82	111	19.40	23.0	poor	poor	male
23.1.82.	55	19.40	23.0	poor	poor.	male.

oysters of the size range 101-120 mm (25). The oysters in between the above two size-groups show very little sex-reversal. It is quite contrary to the findings of Asif (1979) wherein ambisexuality did not occur in specimens at the level of 1.5 cm in length, and the presence of hermaphrodites was maximum in C. rivularis and minimum in S. glomerata. To a certain extent the findings agree with the view of Oldfield(1961) that the sex change normally takes place from an earlier male to a later female phase, as in the case of Kellia suborbicularis and Montacuta ferruginosa.

The present findings agrees with the observations of Rao (1953, 56) on C. madrasensis and agree with those of Coe (1934, 36) on O. edulis who says that animals living under comparatively more favourable conditions have a greater percentage of females than males. Asif(1979) mentioned that certian genetical mechanisms also control the process of sex-reversal. The difference in ecological habitat, prolonged gonadal activity and high temperature do not effect the pattern of sex-reversal in oviparous oysters, as in temperate ones.

The co-existence of factors of optimum food and temperature (28-30^{o}C) has favoured the hermaphrodite oysters to dominate in female characters and thus there is a possibility of sex-reversal. Any temperature higher or lower

than this range and paucity of food does not favour females. Some oysters with male dominating characters were also observed during August and September '81, but feeding was poor in these oysters.

EFFECT OF SALINITY AND TEMPERATURE ON REPRODUCTION

The reproductive cycle of a species is a genetically controlled response to the environment (Sastry, 1970a). The pattern of the reproductive cycle in a species is apparently determined through the co-ordination of successive reproductive events with changes in the external environment. The reproductive cycle may vary in relation to the local environment. The regime of salinity is an important ecological factor in the tidal rivers and streams which show diurnal, seasonal and annual fluctuations. Giese (1959a) and Giese and Pearse (1974) reviewed the influence of exogenous and endogenous factors on the annual reproductive cycle of marine invertebrates including pelecypods. Recent studies indicate that a reproductive response is produced through the interaction of environmental factors, especially temperature, salinity, light and food, with the endogenous factors within an organism. It is also known that a neuroendocrine activity plays a significant role in co-ordinating the physiological process like the reproductive events within the organisms in response to changes in the external environment

(Sastry, 1970b, 1975). In the present investigation the very important factors such as salinity and temperature and their influence on the reproduction of oysters in the Pulicat Lake are studied.

The water temperature, salinity and oxygen of the bed of C. madrasensis is plotted in Fig 2. The percentage frequency of ripe females during the period from July 1980 to June 1982 is plotted in Fig 12. Since these three factors are influenced by the North East monsoon, it has been found quite convenient to divide the year into the following, viz., pre-monsoon (July to September), monsoon (October to December), Post-monsoon (January to March) and summer (April to June). The changes in salinity and temperature and their effect on the spawning of oysters are described below:

PRE-MONSOON : As is seen in Fig.2, the salinity was 31.06‰ during July '80, gradually increasing to 36.56‰ till August, and thereafter decreased to 32.95‰ by September '80. The average water temperature was 30°C, 29.5°C and 30°C respectively for the months of July, August and September '80. During the month of July '80 the percentage of ripe males and females was 14.29 % and 16.7 % respectively, but slightly less during August when gametogenesis started during this month. There was a rise in the percentage of ripe ones during September '80. During

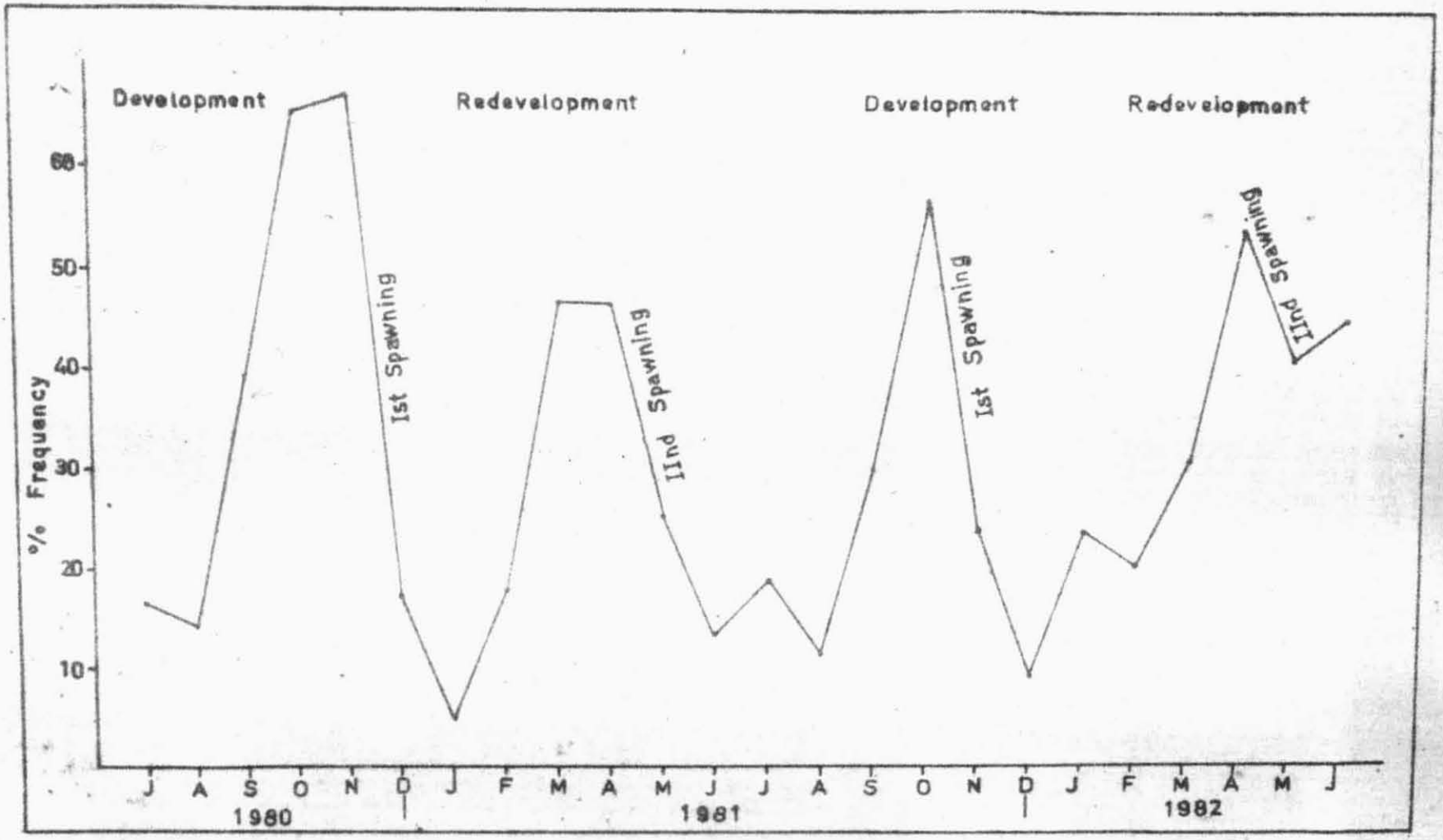


Fig.12 Percentage frequency of ripe female oysters, C. madrasensis, observed during July 1980 to June 1982

the subsequent year, for the same period, the salinity was 29.2‰, 35.56‰ and 32.65‰ and the temperature was 28°C, 28.8°C and 28.5°C for the months of July, August and September 1981 respectively. The percentage of ripe males and females were 15.96 and 19.38 which was subsequently reduced to 12.26% and 11.54% during August. The percentage of ripe ones of either sex increased during the month of September to 56.86 and 30.16, males and females respectively. Salinity and temperature in September seem to be quite congenial for the process of gametogenesis thereby increasing the percentage of ripe females and males.

MONSOON : The process of ripening of the gonad and the subsequent spawning as a result of sudden fall in salinity, and changes in temperature were due to the outbreak of the North East monsoon. In October '80 the salinity and temperature were 29.56°C and 29°C respectively. In November '80 the salinity decreased to 0.37‰ as also the temperature to 28.5°C. The bar-mouth was closed for about 8 days from 11th to 18th November, as a result of which the flood water influxed through the river discharge into the lake has brought down the salinity to a low level. The drop in salinity has a direct effect, so that the ripe females and males suddenly spawn, and simultaneously there was a rise in the spent ones indicating the progress or completion of spawning. The fisher-

men around the lake, who depend upon the lake for their livelihood, dug out a connection with the sea at this time, as a result of which the salinity rose to 16.02 ‰ in December and the temperature has come down to 25.8°C resulting in the extension of spawning to the month of December also. The percentage of ripe males and females during October-November '80 seems to increase gradually, and the same falls suddenly in December to a very low level. Spawning had taken place during the second half of December, the mechanism being triggered by the lowering of salinity in the lake. This is mainly due to the late monsoon during the year 1980. But in the year 1981 the North East monsoon started a month earlier and spawning had taken place in the second half of October itself, extending upto the first half of November. In the year '81, the ripe ones were high during October 1981 and were found to decrease gradually during the months of November and December 1981. Salinity and temperature fluctuations have shown the same trend as in the previous year. The salinity in the oyster-bed was 6.83 ‰ during November '81 and this quite high when compared with the same month of the previous year.

POST-MONSOON : There was a gradual increase in the salinity (25.75 ‰, 30.39 ‰ and 34.14 ‰ and temperature 27.5°C, 29.5°C & 30.5°C) during January, February and March '81. Since the bar-mouth was opened, there was a

tendency for increase in the salinity from January to March '81. In 1982 also the salinity and temperature showed a gradual increase from the month of Jauanry to March. Salinity which was 18.99‰ increased to 32.84‰ and in March it reached 35.29‰. Temperature also which was 21°C during January, by February it reached 27°C. The oysters underwent 'resting stage' or 'inactive' condition during January '81 and in December '81, soon after their spawning. Females which were not 'spent' enter into 'regressive' phase. The relict ova in the lumen undergo cytolysis, thereby resorption was found to occur. After recouping well, the development of the gonad starts again for the second spawning.

SUMMER : Salinity and temperature were found to be high during the summer months. Salinity which was 34.83‰ during April has fallen very slightly to 32.21‰ and the fall of temperature from 31°C to 29°C during the first week of May has triggered the mechanism of oysters to spawn. During May and June '81 there was a rise in salinity from 32.21‰ to 35.41‰ but the temperature was slightly lowerd which very much favour the recovery and the onset of gametogenesis.

DISCUSSION

Temperature and salinity may be considered as the most important abiotic factors influencing gametogenesis and spawning in oysters. The temperature range necessary for reproduction is generally much narrower than the temperature range within which all other physiological functions can occur. The influence of temperature in the reproduction of marine invertebrates, including pelecypods, has been reviewed by Orton (1920), Runnstrom (1927, 1936), Gunter (1957), Giese (1959a), Vernberg (1962), Kinne (1963, 1964 1970), McWinnie (1971), Hedgpeth and Gonor (1969), Loosanoff (1971), and Giese and Pearse (1974). Under temperate conditions, the chief spawning stimulus, in the case of oysters, is the increase in temperature of the water (Stafford, 1913; Churchill, 1919; Nelson, 1928a, b; Prytherch, 1928 and Galtsoff, 1930b, 1932). According to these authors, American oysters fail to spawn until the water temperature reaches 20°C. Nelson (op. cit).found that the maturing process also depends upon temperature and observed further that the reproductive elements are actually absorbed when the required temperature is not attained. Galtsoff (1930, 1932 & 1938) said however, that female oysters spawn even at a lower temperature range of 18.6°C to 20.5°C in the presence of male reproductive elements. Loosanoff and Engle (1940) pointed out that there was a

considerable lag between the time when water reaches the critical temperature (20°C) and the time of actual spawning of C. virginica in the Long Island Sound. Though a few oysters in early stages of gametogenesis were observed during May and June, there was no gametogenic phase during winter, as has been reported in C. virginica by Loosanoff (1942). Loosanoff and Engle(1942) found C. virginica at different depths, all spawning simultaneously at the critical temperature. Loosanoff and Davis (1950) induced mass spawning in O. virginica at the temperature of 15°C and 15.8°C and thereby concluding that temperatures prevailing during the period of gonad maturation may determine the temperature at which the first spawning will take place. They were able to force oysters into double breeding by manipulation of the temperature and thus emphasized the importance of temperature as a factor controlling the oyster breeding (Loosanoff and Davis, 1952). According to Loosanoff and Nomejko(1951a), the Chesapeake Bay races of C. virginica usually do not spawn in the Long Island Sound because of too low temperature, but develop large gonads and get fattened and will spawn if moved inshore to warmer waters of shallow or enclosed estuaries. Crassostrea requires warm waters of usually 20°C-25°C for breeding (Andrews,1979). In Crassostrea, oysters from colder regions mature and spawn more readily in the lab than those from warmer areas

when the temperature appears to be less effective as a stimulus (Loosanoff, 1969).

The period of gonad growth and gametogenesis in a number of species has been correlated with seasonal changes in temperature. In many species, gonad growth and gametogenesis seem to occur with declining temperatures in the fall or with increasing temperatures in the Spring and Summer. In Mercenaria mercenaria from the Long Island Sound, gametogenesis starts in September and maturity of gametes attains by December (Loosanoff, 1937b). During Winter the gametogenic activity is slow and in Spring when the temperature reaches 15°C, vigorous development of spermatozoa and oocytes occur and spawning commences in Summer when temperature reaches 23-25°C. Gametogenesis in Cyprina islandica begins with declining temperatures (Loosanoff, 1953). Quayle (1943) observed Paphia staminea from British Columbia that though the gonial cells formed immediately after spawning, they reached maturity only in April. Calabrese (1969a) reported that gametogenesis occurred in Mulinia lateralis from the Long Island Sound throughout the year, but at a slower rate during Winter. In the case of Astarte sulcata, gametogenesis begins in January, when temperature is at the minimum, spawning takes place when the temperature declines from 15°C to 10°C. Under some tropical climatic conditions depending upon the annual variations in temperature, gametogenesis

also appears to be restricted to certain periods in the year (Tranter, 1958a, c and 1959).

The population of Argopecten irradians from Massachusetts, and North Carolina reaches maturity in July with an increase in temperature, approximately 23°C, and in the North Carolina population, gonad growth and gametogenesis begin later when the temperature is above 20°C, and the gametes do not develop to maturity until the end of Summer when temperature is about 26-28°C. It is also clear that the successive events in the reproductive cycle of these two populations occur at different environmental temperatures (Sastry, 1966, 1970a). Von Oertzen (1972) reported that the Arctic bivalves in the Baltic sea had ripe eggs and sperms for prolonged periods and shifted their breeding period to Winter or early Spring. Wilson and Hodgkin (1967) have determined the annual reproductive cycle of five species of mytilids and correlated them with seasonal changes in temperature. Gametogenesis begins in Spisula solidissima immediately after spawning in December, and the animals mature by May-June when temperature is about 10°C. Spawning occurs in July and August when the temperature rises from 9.6°C to 18.9°C during the early part of September (Ropes, 1968). Cold climatic conditions delayed gamete development to maturation in Mercenaria mercenaria (Loosanoff and Davis, 1963) and Mytilus edulis(Bayne,1965).

Rope and Stickney (1965) and Pjitzenmeyer (1965) have reported that the soft shell clam, Mya arenaria develops gametes both in Fall and Spring in areas of South Cape Cod while in the north there is only one period of reproductive activity in Summer. Hopkins (1937), Hori (1933) and Coe (1931) found a critical temperature for spawning. Korringa (1957) however, observed that there cannot be any critical temperature for a species as a whole. Smith (1949) indicated that there is no mass spawning as a result of stimulation by temperature but rather a constant release of sex cells in small quantities from maturity of gonads to their exhaustion.

However, in tropical waters there may be very little annual variation in temperature. Even under these nearly uniform conditions spawning may not be spread over the whole year. A number of species have a prolonged breeding season, yet it is restricted to specific months of the year (Rao, 1952; Abraham, 1953; Nayar, 1955; Sastry, 1955; Alagarswami, 1966). In the other Indian pelecypods, spawning takes place throughout the year, even though the peak is limited to certain months (Anthony Raja, 1963; Narasimham, 1969).

In the Pulicat Lake, the range of temperature during the period of study was between 22.5°C during January 1982 and 32°C in May 1981. During the peak spawning, the temperature which triggers spawning lies between 29.5°C and 25.5°C

which was found during November and December '81 respectively. The temperature during the previous month of spawning was observed to be 29°C. The temperature has fallen at the end of November as a result of heavy North East monsoon rains in the lake and was lowered to 25.5°C during the first week of December 1980, so as to favour the releasing of the gametes into the water. In October 1981, the temperature of 29°C which was lowered to 26°C in November and was further reduced to 23.5°C and 22.5°C during December '81 and January '82. During this period, even though there was reduction in temperature during the month of December '81, the peak spawning was completed during the first half of November '81, when the water temperature was at 26°C. Hence, from this it can be presumed that apart from temperature, other factors also are involved in the spawning of oysters during the peak spawning at Pulicat.

During March 1981 the water temperature was 28°C which favoured the gametogenesis and thus helped 47.01% of the female population to reach the ripe condition during April '81. The temperature rose from 31°C to 32°C on the 26th April and it was maintained upto the first week of May, and this has triggered the spawning. There was no marked fluctuation in the salinity of the environment except for very minor variations during the second peak spawning. Temperature alone seem to have played a major

role in spawning, and this agrees with the view of Dinamani (1974) and Roughley (1933). Mahadevan (1980) reported the period of high salinity and high temperature during April-May coincides with the ripening of gonads resulting in a spawning peak at Tuticorin.

In the case of Pinctada albina (Tranter, 1958a) and in Sphaerium simile (Zumoff, 1973) the breeding was observed throughout the year with definite variations in different reproductive activities at different times. In many other bivalves, such as Donax cuneatus (Rao,1967), Parreysia corrugata (Lomte and Nagabhushanam, 1969), Placopecten magellanicus (Naidu, 1970) and others, the activity is restricted to a certain period of the annual cycle. There may be one or two cycles of reproductive activities as in Mya arenaria (Shaw, 1965); Mytilus edulis planulatus and Xenostrobus pulex (Wilson and Hodgkin,1967) and Katelysia opima (Mane, 1973); C. madrasensis(Hornell, 1910, 1922); Chidambaram and Dinamani as reported by Devanesan and Chacko (1955), Rao and Nayar (1956), Rao 1953, 1956); C. cucullata (Awati and Rai, 1931), Asif(1980); and Donax faba (Alagarswami, 1966). Likewise, a prolonged spawning period with two peaks in November and April/May in C. cucullata is also reported from the coast of East Africa (Van Somersen and Whitehead, 1961). In Mya arenaria from the North Cape Cod (Ropes and Stickney, 1965) Donax cuneatus(Rao, 1967), Parreysia corrugata (Lomte and

and Nagabhushanam (1969), Placopecten magellanicus (Naidu, 1970), Spherium similis (Zumoff, 1973), Saccostrea glomerata from New Zealand (Dinamani, 1974) there is only a single reproductive cycle. The pearl oyster Pinctada albina from Australia, spawns actively during Autumn (Tranter, 1958a). In other species, P. margaritifera, spawning is limited to early Summer and Autumn (Tranter, 1959). In all these three species minor spawning also occurs outside the major spawning period.

In C. madrasensis two peaks of spawning are observed though there are ripe ones throughout the year. Probable chances are there, occasionally for a third spawning also by the lowering of salinity as a result of untimely rains on the lake. This agrees with the views of Tranter (1958a, c & 1959) as described above.

Salinity is one of the most fluctuating environmental factor in the Pulicat Estuary. Changes in salinity are responsible for the stimulation of spawning in most of the tropical invertebrates. Hornell (1910a) recorded peak sexual activity in C. madrasensis on the east coast rivers and backwaters between October and November and considered a fall in salinity but not a rise in the water temperature, as the main stimulating factor. Again he(1922) recorded the peak spawning in oysters in March-April with stray spawnings in between and also any sudden fall

in salinity to induce additional spawnings. Sundar Raj (1930) mentioned that a salinity range of 8.42‰-29.9‰ favours breeding and early development but this is a very wide range. Hori and Kusakabe (1926) observed the adverse effects of low salinity on the development of eggs of the common Japanese oyster. Reproduction in some pelecypods from the Madras Harbour has been correlated with salinity changes (Panikkar and Aiyyar, 1939; Paul, 1942). Ranson (1943) has observed in Gryphaea angulata, a gradual degeneration of tissues in waters of salinity below 7‰. Butler (1949) found that gametogenesis was inhibited in oysters until the salinity level was increased to above 6‰. Rao (1951, 56) found the optimum salinity of 22.26‰ requirement for the development of eggs in the Adyar estuary where the salinity fluctuates over a wide renge of 0.3‰ to 41.1‰ and also observed that spawning does not occur unless the optimum salinity is reached by the influx of rain water or by opening of the bar as in the Ennur backwaters. In Placuna placenta from the Kakinada Bay, development takes place during periods of high salinity, and spawning begins with the dilution of sea water by monsoonal rains (Sastry, 1955). Durve (1964) observed the gametogenic activity in Meretrix casta during fairly stable temperatures, specifically between 27°C and 33°C and at a salinity of 15‰ and he also observed spawning in C. gryphoides during July to September at Kelwa

waters. In Donax faba from the east coast of India, gametogenesis takes place with the increasing salinity following the monsoonal rains (Alagarswami, 1966). In Donax cuneatus on the Madras coast a single reproductive cycle occurs and gametogenesis takes place between September and December when the temperature and salinity are low (Rao, 1967). The gametogenic activity of the wood-boring bivalve Martesia striata is interrupted with a decrease in salinity during the period of monsoonal rains (Balasubramanyan, 1970). Nair and Saraswathy (1970) have reported that the shipworm Nausitoria hedleyi breeds when the salinity is low and passes through a resting period when the salinity is high. According to Purchon (1968) Egerina radiata depends on increased salinity for breeding purposes. Wilson (1968, 1969) has reported that the reproductive activity of the mussel Xenostrobus securis is limited by salinity in the Swan Estuary, Australia. Prolonged exposure to low salinity causes gonad resorption and gametogenesis is inhibited at very low salinities.

Salinity fluctuation at the Pulicat lake was very wide during the period of study ranging from 0.37‰ during the North East monsoon season to 36.56‰ during the pre-monsoon period. The gradual increase in salinity during April-May from 32.21‰ to 36.53‰ has favoured the gametogenic activity of C. madrasensis. The main peak of spawning of oysters was observed during the second half of

November when there was a fall in salinity, extending upto the first half of December 1980, during which period the salinity was ranging from 0.37‰ to 16.02 ‰ In the subsequent year, October and November 1981, the salinity in the bed was observed to be 14.99‰ and 6.83 ‰ and as a result of this decrease in salinity from 32.65‰ to 14.99‰ in October, spawning commenced and the intensity was very high during November '81. A secondary peak of spawning during April-May '81 was observed and the salinity of 34.14‰ was lowered to 32.21‰, and the temperature was slightly raised as a result of which spawning was commenced. Shorter spawning duration results when all the individuals of a species react simultaneously to the co-ordinating factors. From the above, it is clear that the spawning of oysters in the Pulicat lake synchronises with the heavy rainfall during the North East monsoon and with the increasing temperature during the summer months, thus agreeing with the earlier work of Rao (1953), Hornell(1910, 1922), Sundar Raj (1930), Sastry (1965), Rao (1967), Durve (1965), Balasubramanyan (1970), Nair and Saraswathy (1970) and Stephen (1980).

There was an indication of sex change in some oysters of C. madrasensis during the pre-monsoon, monsoon and post-monsoon seasons. There are different opinions about sex-reversal which is mainly due to the interaction of food and temperature. Rao (1956) suggested the possi-

bility of the influence of environment such as salinity and temperature in the determination of sex in the Madras backwater oyster. The higher salinity and temperature favours the changing of sex, from female to male. Lower temperature, moderately high salinity and poor food in the environment as well as in the gut of the oysters also initiate its sex change from female to male. At the same time, immediately after spawning, change their sex from female to male. This is mainly due to the lowering of temperature.

It agrees with the view of Tranter (1958a) who suggested that Pinctada albina reacts differently to the environment in order to achieve the sexual phase suited for its nutritional conditions, and Sastry (1966, 1968) also found the development of ova and spermatozoa being influenced by temperature and food levels. Coe (1936) suggested that feeding deterimines the sex, and under favourable conditions females predominate over males, Awati and Rai (1931) found that the commensal pea-crab Pinnotheres reduces the normal food supply of the oyster host so that majority of the infested oysters become males.

There were wide fluctuations between the male and female numbers in the oysters population. In the pre-monsoon, the percentage of females in the population was found to be very high and males considerably very low. Immediately after heavy showers, during the monsoon period,

the percentage of females goes down and as a result males predominate in the population. The percentage of females again falls considerably to 36 from 51 of the previous month and the percentage of males and indeterminates was found to increase markedly in the population. During this period the entire bed was exposed and temperature and salinity also were found to increase considerably. In the meantime, the rate of filtration of food also was very limited and as a result males dominate the females in the population.

CHAPTER THREE

SETTLEMENT OF OYSTER-SPAT (*CRASSOSTREA MADRASENSIS*) IN THE PULICAT LAKE.

In any culture practice, a steady supply of seed or young ones, or spat in case of oysters, is the most basic need. Natural oyster production is extremely unpredictable and is steadily decreasing due to various hazardous factors in the environment, including predation. Attempts to utilise natural seed oyster production as efficiently as possible are continuing, but even at best the supply from this source is too small and too unreliable to support a viable industry. In most of the industrialised countries water pollution has wiped out large areas of natural oyster-beds and has even destroyed the coastal fisheries. To combat this depletion of stocks new methods of fish and shellfish cultivation are being developed. The most promissing locations for these developments on the Indian coastal waters are the bays and estuaries unaffected as yet by any pollution.

In the case of oysters, the seed, popularly called the spat, is available in millions in the vicinity of the mother-oysters, since their fecundity is very high. The setting of larvae however is hampered by predation by other animals and by encountering unfavourable environmental circumstances. The spat, when settled, is used for further rearing upto a marketable size in a conventional farm. For the collection of spat several types of cultch, viz., stone, glass sheets, plastics, oyster shells, Pecten shells, mussel shells, pebbles, twigs, earthen pipes, asbestos sheets, netron, tiles, wooden collectors, ropes and cages have been used in different countries, in different ways depending on the local topography of the coast, availability, cost and easy handling of the cultch.

The information on the methods of spat collection in India is very scanty. Hornell (1910, 1922) reported the use of roofing tiles for spat collection on the Pulicat Lake. Devanesan and Chacko (1955) tried casuarina twigs, oyster and cockle shells but did not obtain encouraging results. Nair (1975) reported the suitability of using cement-coated tiles at Athankarai Estuary. Sundaram and Ramadhoss (1978) reported the suitability of lime-coated tiles at Tuticorin. The other important work on oyster spat are of Rao (1951), Rao and Nayar (1956), Reuben et al., (1980), Thangavelu and Sundaram (1980) and Nayar and

Mahadevan (1980) at Tuticorin, Purushan et al., (1980) at Cochin backwaters; Dhulkhed and Ramamurthy (1980), Joseph and Joseph (1980), and Stephen (1980) on the Mulki Estuary.

Breeding and settlement of oyster spat in other countries have been studied by Roughley (1922), Nelson and Perkins (1931), Croft (1968), Carriker (1951), Cole (1938), Haskin (1964), Malcolm (1971), Hidu and Haskin(1971), Hickman and Gruffjdd (1971), Thorson (1950), Sakuda (1966), Quayle (1969), Cranfield (1973), and Wisely et al., (1979a,b,c). Hanging culture is by far the most productive method originated in Japan in 1923 (Seno and Hori,1927). Fujiya (1971) and Korringa (1976) have described the Japanese hanging culture method in detail. The behaviour of Crassostrea virginica (Gmelin) at settlement has been described by Nelson (1924) and Prytherch (1928) and that of Ostrea edulis by Cole and Knight-Jones (1939), Butler (1955), Galtsoff (1960), Dix (1975 & 1979), Cranfield(1970). The settlement of spat of C. gigas has been studied by Haskin (1964), Loosanoff and Engle (1940), Loosanoff and Davis (1952), Loosanoff and Nomejko (1951b), Yokota (1936) and Wisely (1979).

MATERIAL AND METHODS

In order to investigate the frequency of larval abundance and intensity of spatfall, a sampling station opposite to the Estuarine Biological Laboratory was

established.

A small model rack of the size of 2 m X 1.5 m was constructed by driving the country wood (Casuarina) into the muddy bottom. Poles were tied horizontally just below the surface of water and perpendicular to these poles transverse poles were arranged very closely to form a rack, thereby the gap between them was very little, so as to protect the tiles from falling down from the rack. Roofing tiles of the size of 22 x 12 cm were procured locally. For every season 50 tiles were used for spat collection. The tiles were cleaned and then coated with lime as described by Thangavelu and Sundaram (1980). After drying, the tiles were arranged on the rack in the form of a crate. In addition to the tiles, old whithered oyster shells about 100 numbers also were placed in a 45 x 30 cm bag made out of 2 mm synthetic twine with a mesh size of 20 mm and the bag was suspended from the rack constructed for laying the tiles. The tiles and shells in the mesh bag were examined after a period of 15 days. The spat settled on the cultch was located and the number of spat on each cultch was counted. Though mortality during the sampling period was low, yet barnacles, bryozoans and Anomia etc., were noted to be competing for settlement space along with the spat.

Plankton samples also were collected from the lake by filtering 200 litres of water through a small 30 cm diameter hand-net made out of fine-meshed bolting silk. Plankton was preserved in 2 percent formalin and was analysed by using the plankton counting chamber and the number of bivalve veligers present in 100 litres was calculated. Salinity, temperature and oxygen also were recorded from the same locality simultaneously.

RESULTS

RELATION BETWEEN THE RIPE OYSTERS AND THE NUMBER OF LARVAE IN PLANKTON

The percentage of ripe male and female oysters in the total oyster population, throughout the period of study, is illustrated in Fig.13. Maximum number of fully ripe oysters of both the sexes were found during the months of April and October for the two years, from July 1980 to June 1982. Immediately after the outbreak of the North East monsoon, due to the freshwater influx into the lake, the salinity decreased to a low level during October/November, triggering the mechanism of oysters to spawn. Lowering of salinity due to summer showers also during April induces the animals to liberate their gametes into the water. As a result of spawning, the percentage of ripe ones in a population declines in the subsequent months.

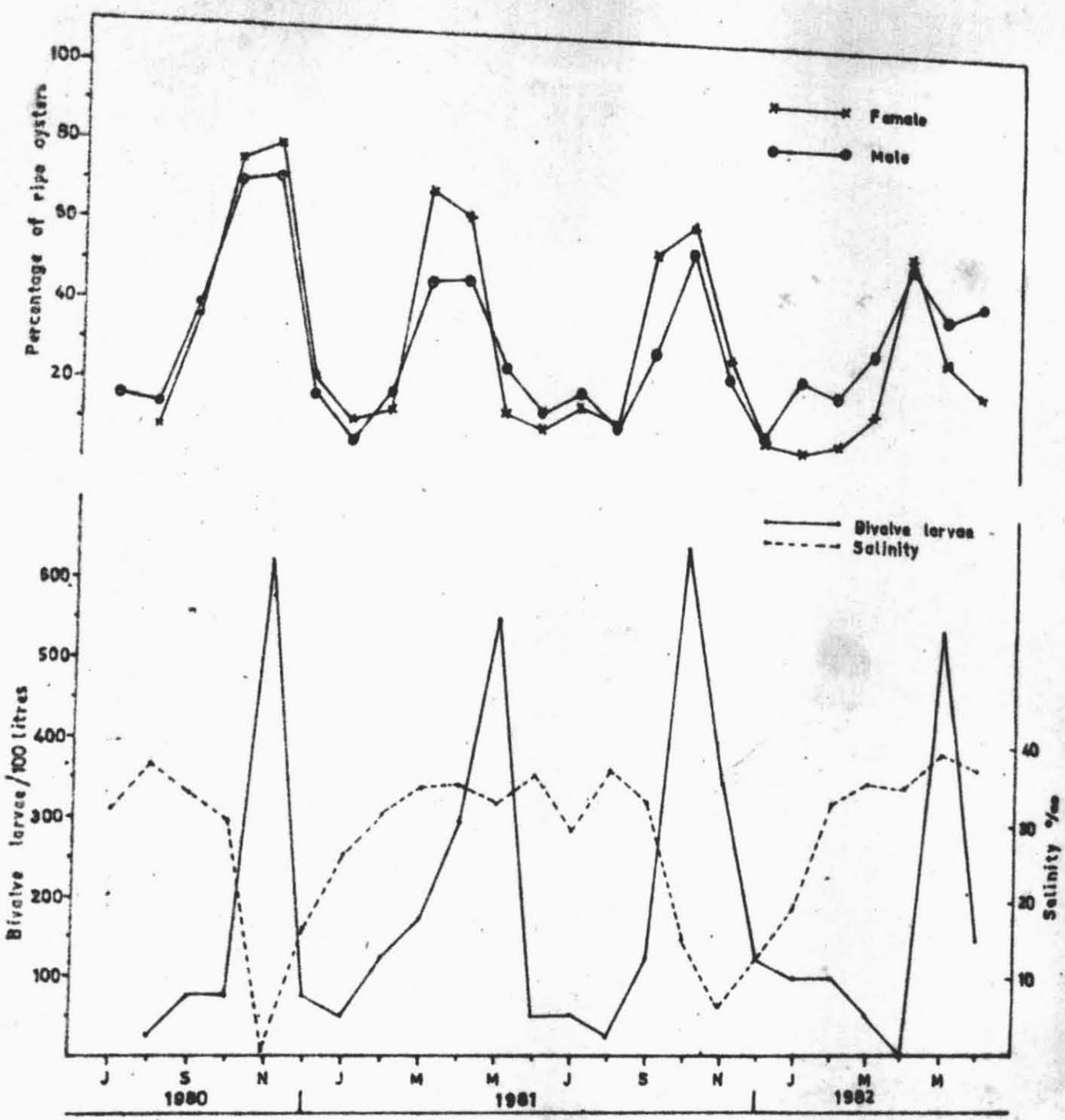


Fig. 13 Seasonal variations in the abundance of bivalve larvae observed during July 1980—June 1982 and correlations with the salinity and the ripening of oysters.

The maximum percentage of ripe males and females during October 1980 was 75.68 and 70.45 respectively, which rose to 80% and 72% during the month of November 1980. Since there was a delay in the onset of the monsoon showers in 1980 on the Pulicat Lake, which started only in November in 1980, all the ripe oysters started spawning only during this period. As a result, the ripe oysters declined in the subsequent population. Another peak of ripe ones was observed during March/April 1981, and it was 46.49/46.47% in females and 60/64.1% in males respectively. It was found to decline to 25.4 % and 13.64 % in females and males respectively during the month of May. The same case was observed during the corresponding months of the subsequent year also. In October 1981, the percentage of ripe males and females was 63.48 and 56.7 respectively, but declined in November itself, showing that October is the peak period of spawning.

The presence of the early stages of oyster larvae (veligers) in plankton also indicates the recent spawning, and their numbers would indicate whether it was a major or a minor spawning. A knowledge of the larval growth and the duration of the larval period at the prevailing temperature and salinity will enable a prediction of the approximate time of spatting, correct upto day or so. Based on the trend in the reduction of the number of larvae in

the plankton samples, a firm prediction can be made of the approximate time of spatting.

The backwater oyster remains sexually active throughout the year with intensive spawning periods during lower salinity or high temperature which are all suitable for early development. Following the spawning early veliger larvae occurred in the plankton of the open backwaters. The presence of oyster veligers in the plankton of the lake waters was observed throughout the period of this study, with two peaks in an year. The spawning of oysters has taken place in November 1980, and during the same month there was a major peak of larval occurrence in water, indicating the major spawning during this month. The number of larvae was found to be declining slowly during the next month. The bivalve veliger larvae was found in the plankton in the subsequent months also, but they were in negligible in numbers. In all the above, the occurrence of the veligers coincided also with the maximum percentage of oysters in the spent condition. Again in March/April the oysters were found to spawn and another minor peak of larvae was observed in the lake waters. During October 1981, the peak occurrence of larvae was observed to be considerably higher than in the previous year. The higher number of larvae during this month was attributed mainly to the presence of higher salinity which

particularly favours the larvae greatly than in the previous year.

RELATIVE ABUNDANCE OF VELIGERS IN RELATION TO SPATTING ON THE CULTCH

Based on the examination of the ripe oysters and their percentage in the total population, the quantity of larvae produced and the number of seeds collected, the efficiency of seed collection could be determined. Tiles were laid on the model rack during October 1980, which was the peak period of spawning. The spat collections on the tiles showed that the average number of spat settlement was 3 per tile, whereas in the case of shells no spat settlement was noticed (Table-13). Though the density of larvae was calculated to be 525 for 100 litres of water, the settlement during this period was very poor. The salinity and temperature parameters of the water were correlated and it was found that the salinity during this period was low. The low salinity 0.37‰ was maintained for a period of eight days due to continuous rains. Such lower salinity probably does not favour the growth of larvae and thus the settlement was also very poor. In April 81, the average settlement was 19.04 $\pm$ 10.98 and 2.04 $\pm$ 1.88 on both tiles and shells. The spatfall during this period was less when compared with the

Table. 13

Efficiency of two types of spat collectors; each value represents average (± S.D) number of spat collected from 50 tiles or 100 shells.

Type of spat collector	Period of spat collection					
	Apr/May 1980	Oct./Nov. 1980	Apr./May 1981	Oct/Nov. 1981	Apr/May 1982	Oct./Nov.1982
Lime-coated tile	33 ± 9.9	2.6 ± 2.29	19.04 ± 10.98	27 ± 20.42	51.5 ± 16.51	2.4 ± 2.37
ter shell	4.46 ± 2.23	0.0 ± 0.00	2.04 ± 1.88	2.94± 2.48	3.71 ± 2.90	0.0 ± 0.00

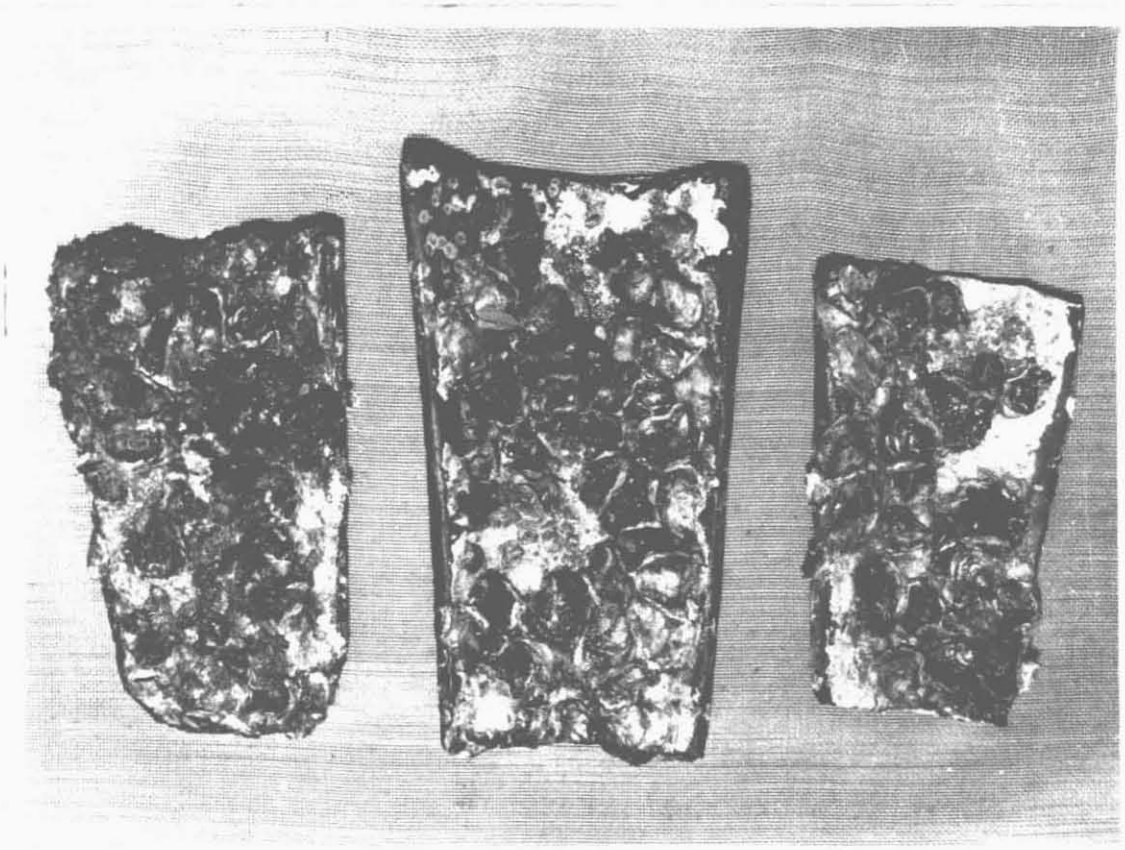
previous year for the same month (33 ± 9.9). In October 1981, the average settlement of spat was 27 ± 20.42 per shell and the number of veligers in 100 litres of water was 650. Salinity was slightly higher than in the previous year. There was a good settlement of spat both on the tiles and on the shells upto 51.5 ± 16.51 and 3.71 ± 2.9 respectively. While comparing the two years, the setting of oyster spat was considerably high during April/May and the settlement was poor during October/November. Though the peak spawning and peak occurrence of larvae was during the month of October/November, when the North East monsoon was at its height, yet the settlement was poor, perhaps due to the low saline conditions prevailing in the lake.

SALINITY AND SETTING OF SPAT

Salinity is an important ecological factor in the lake which shows diurnal, seasonal and annual fluctuations in the environment. The time of spawning and the peak occurrence of oyster larvae are probably regulated by the seasonal salinity patterns. The seasonal variations in salinity in relation to the abundance of larvae in plankton are illustrated in Fig. 13. There was a peak period of spawning during the month of November 1980 when the relative abundance of larvae in the lake was found to be very high, but the settlement was poor. This is probably

TILES WITH OYSTER SPAT

PLATE 11



due to the poor larval development in the low saline conditions which would have delayed the setting stage. Thus there is a possibility for the mortality of veliger larvae in the lake during these low saline periods. In the subsequent months, the salinity increased gradually reaching 34.14‰ in March. The next peak of spawning was in April '81 when the salinity was 34.83‰ and the larval abundance in the plankton samples was also noted during this period. Since there was no remarkable changes in the salinity of water during April, there was no danger of mortality of the larvae and the settlement of spat also was considerably high. In October '81 the salinity rose to 6.83‰ as a result of which the settlement of spat also was considerably higher during this period. It is obvious that this salinity range was favourable for the larval development and thus there was an average spat settlement of 27 $\pm$ 20.42 per tile and 2.94 $\pm$ 2.48 per shell. Again in April 1982, the settlement of spat was very high when compared to the earlier months, but in October 1982, the settlement was very poor as was for October/November 1980 also. By and large, the settlement was higher during the month of May 1982 when the salinity was also high.

From this, it is clear that the larval development, growth and settlement of oysters are mainly influenced by the salinity in the lake. Below the salinity level of 5‰,

oysters cease to feed and hence the growth gets inhibited (Galtsoff, 1960). The larval development, growth and settlement were moderate in the salinity range of 6.83‰ to 39.24‰. There were more probable chances even for the mortality of the larvae below the salinity level of 6.83‰.

OTHER FACTORS REGULATING THE RATE OF SETTING OF OYSTER SPAT

The settlement of oyster spat on the cultch is greatly influenced by biological and environmental conditions. There are some favourable conditions such as extensive oyster beds, with adult stock scattered everywhere, suitable rise in water salinity and temperature during the summer months which facilitate a healthy growth of the larvae, a sharp fall in salinity during the North East monsoon which triggers the rapid spawning of oysters, suitable physical factors like tides, waves and winds which contribute to the dispersal or accumulation of these larvae, a water surface suitable for seedling in the lake and a substratum or shells free from fouling for a good settlement. There are certain other factors which by direct or indirect means do not favour the settlement.

The salinity of the Pulicat lake water is usually favourable for the growth of the larvae and setting during the summer months of April and May. In October '81, the number of veliger larvae was high as 70 per 100 litres of

water in the lake and the settlement was found to be an average of 27 per tile and 2.94 per shell, where as in April and May '82 the number of veligers was low as 55 per 100 litres of water and the settlement on cultch was observed to be 51.5 ± 16.51 per tile and 3.71 ± 2.9 per shell. This shows that though the larvae in the environment were high during October 1981, the settlement was poor, whereas in April, '82 the number of veligers was considerably low during April, but settlement was good. Though the salinity of 6.82‰ during October '81 favours the abundant occurrence of larvae, yet it does not favour the healthy settlement of spat. This was probably due to poor growth of the larvae in lower saline conditions, or mortality might have occurred because of over-silting or lack of larval food in the water, or mortality might have been even due to predation.

The distribution of larvae in the Pulicat Lake is controlled by 1) water current, 2) the flow of water from the rivers, 3)the force of winds, and 4) the tidal stream. The flow of waters from the rivers brings down the salinity to a minimum level, which would kill the larvae at times, and mud brought by the riverine water gets deposited on the cultch and does not facilitate the larval settlement. Also the prevailing turbidity and fast flow of water does not allow the penetration of light and these factors have considerably impeded the settlement during the North East

monsoon. Since the larvae are floating on the water surface(pelagic), they are easily drifted by the force of the wind along the deflecting water current. The larvae which are produced by the mother oysters in the natural bed are carried towards the mouth of the lake during the low tides and they are carried in different directs during the high tides and thus they get accumulated in the creeks and bays within the lake. Thus there is the possibility of larval dispersal by the coastal currents also to some extent.

The thick algal growth in the lake and the drifting algae also play a role in settling on the same cultch material and undergoing putrifaction, thereby not only preventing the settlement of spat but also choking the spat. Light also has its effect on the distribution of spatfall, either on the upper or on the lower surfaces. The maximum intensity of spat settlement was noticed on the concave or lower side of the tiles indicating the preference for the darker area rather than on the convex side facing the sun. Accumulation of silt is particularly dangerous to young oysters, which may be smothered or prevented from feeding.

As a result of the heavy monsoon rains, silting was very high during the months of October and November mainly due to the freshwater influx into the lake. The intruding water currents completely churned up the muddy or slushy

bottom of the lake and the silt was lifted up. The deposition of this silt was heavy on the convex side of the tiles and this did not permit the larvae to settle on it whereas during the summer months this type of silting also was very minimum.

The diurnal observations of oxygen, salinity and temperature during October 1981, showed remarkable fluctuations in all these three factors (Fig.14). Monthly average atmospheric and water temperature of the oyster bed of Pulicat lake has been illustrated in Fig.15. Sometimes, depletion of oxygen was found to occur in the early dawn hours which suffocate the larvae or the recently settled spat on the cultch. Thus oxygen plays a great role in reducing the survival rate of the settled spat. The same type of mortality of oysters due to depletion of oxygen during certain seasons in Seti Bay, France has been reported by Nayar (1982). Apart from all these factors, predation by the plankton feeding fishes may reduce the larval occurrence before its settlement.

FUTURE PROSPECTS OF OYSTER CULTURE AT PULICAT LAKE

Although potentially rich areas of oysters, clams and cockles exist in the estuarine waters of India, attempts for culturing these have not been quite popular. In tropical countries like India, oyster growth is very fast and

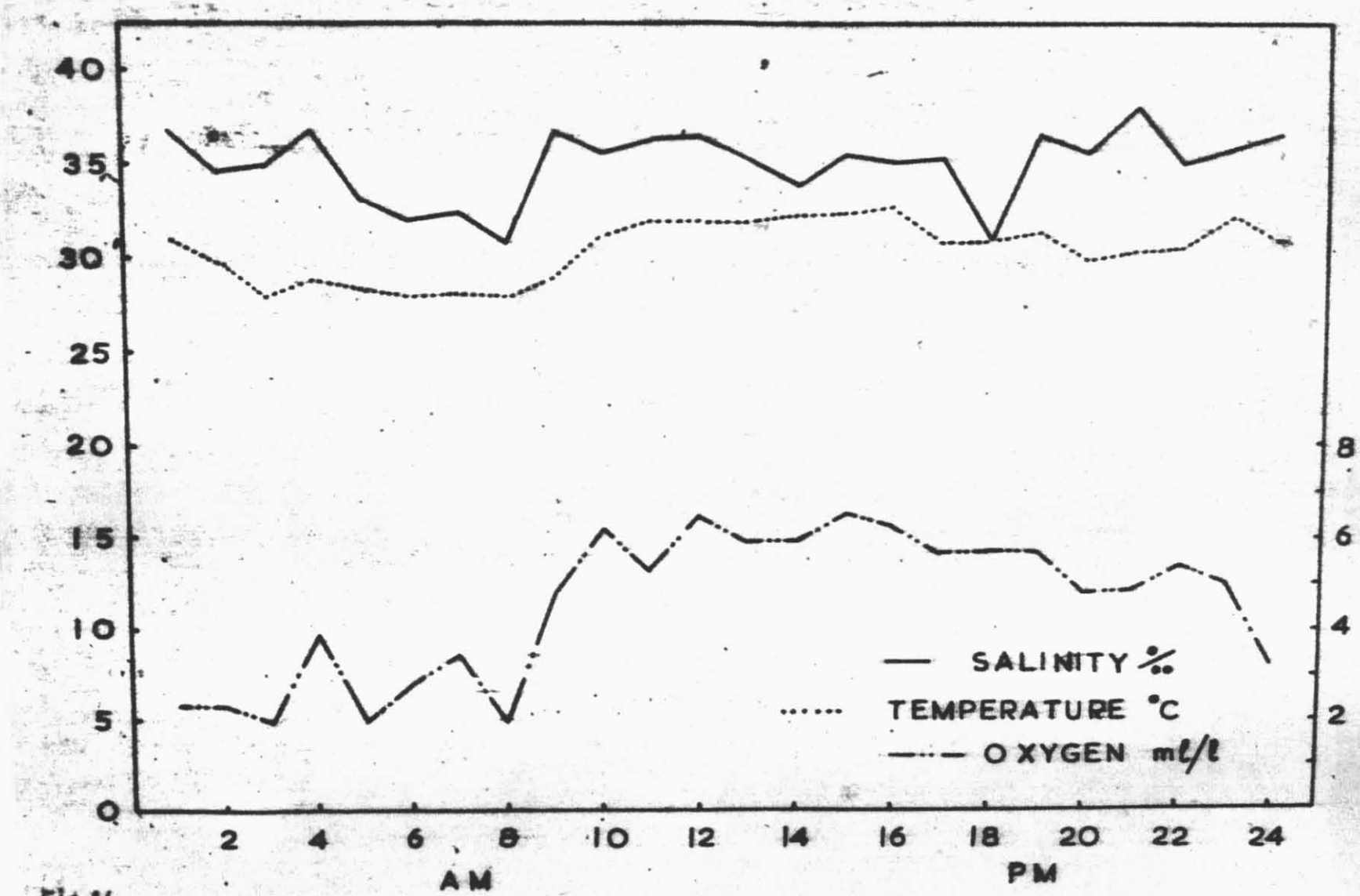


Fig.14 DIURNAL VARIATIONS IN SALINITY TEMPERATURE AND OXYGEN IN THE OYSTER BED AREA

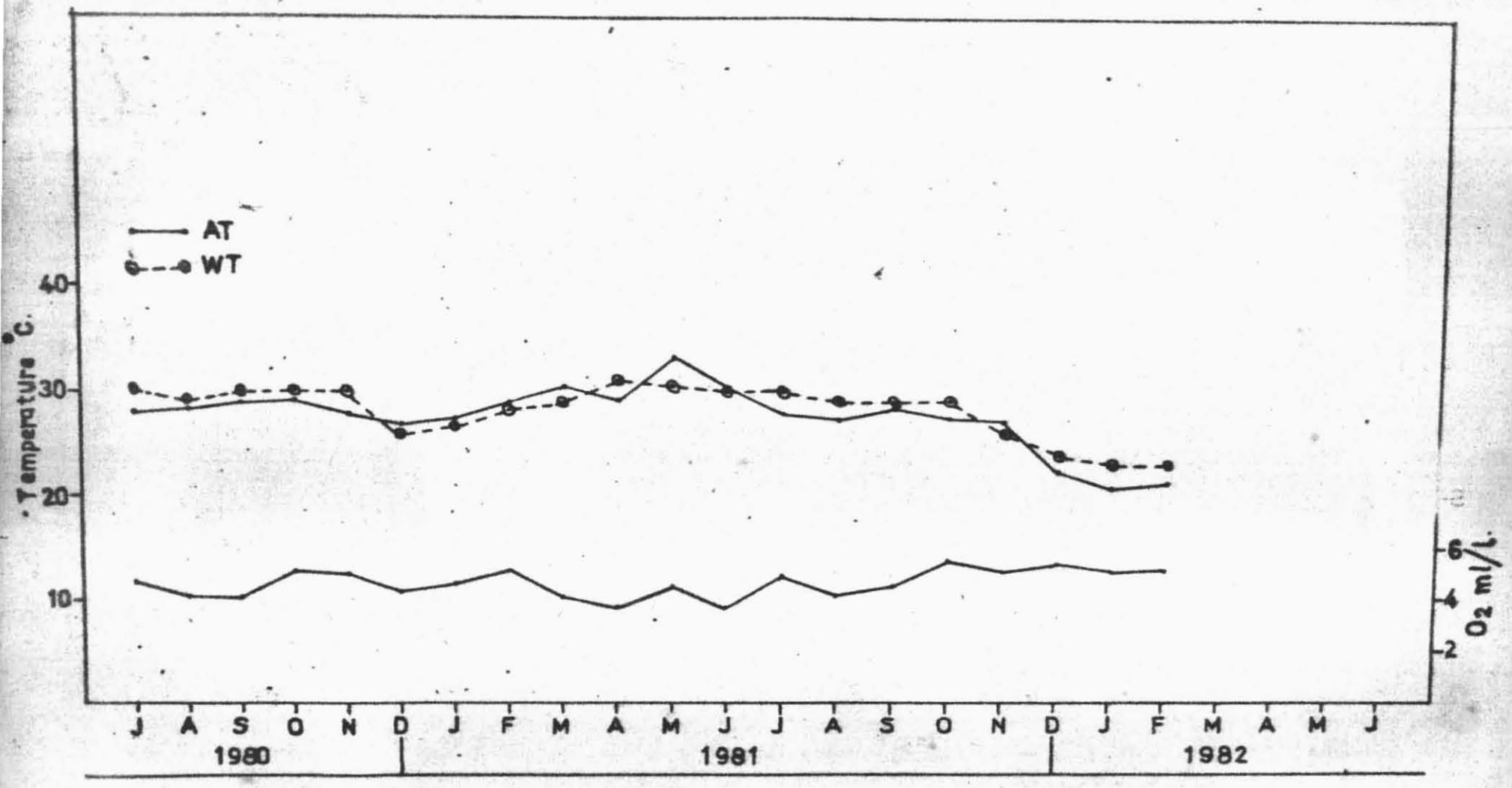


Fig.15 Monthly average atmospheric and water temperatures and the dissolved oxygen in the oyster bed of the Pulicat lake.

within an year it reaches marketable size. According to the FAO statistics for 1980, the total production of oysters throughout the world has reached 9,72,885 tons (Calculated weight including shells). Bell (1970) has estimated that the consumption of oysters in the world by 2000's will attain level exceeding 2,270,000 tons (with shells). A predominantly vegetarian country like India, which depends upon rice and wheat etc., as the staple food may not relish oysters as food. Even then the research on oysters, especially in the development and improvement in culture techniques has considerably progressed nowadays in India. Since the coastal areas around the Indian peninsula are not so polluted as in other countries, brackishwater bodies like the Chilka, Pulicat, Vembanad lakes and estuaries like the Adyar, Vellar etc., could be used for large-scale culture of bivalves to meet the protein deficiency in the country. Now, there is a greater demand for farm-grown oysters in the country and export could also be done to the other countries in due course.

Pulicat Lake is a negative farm of estuary, where the northern parts of the lake are dominated by freshwaters during the monsoon season, and by hypersaline conditions due to evaporation during the summer. The lake is free from pollution and hence is an ideal place for the culture of shellfish. There are large stretches of suitable substrata in the shallow waters for culture by simple and

inexpensive methods. During the extreme fluctuations in the tidal levels during March to June, the oyster-bed gets exposed completely. The periodic catastrophy due to the recession of water level was also reported by Hornell (1910). There are vast areas which will never dry even in the years of extreme drought so that these could be fully utilised for the culture of oysters, both by bottom and off-bottom culture methods. Even the shallow areas which dry up periodically could also be used for culture since the growth of the oysters is very fast and harvest can be done before the recession of water sets in.

Based on the present experiments on the settlement of spat on the Pulicat lake for these three years, it is recommended that the spat collection could be successful during April/May but not so much during October/November. During rainy season in October/November there are some losses or poor settlement due to excessive dilution of the lake water. The growth is also affected by the low saline conditions prevailing in the lake during this period. So the areas wherever the influx of freshwater is heavy may be avoided and areas where the tidal water constantly flushes may be chosen for such oyster-farm operations. Based on such considerations, the area near the village Karimanal and the area north of Kottakuppam Lock are recommended to be suitable for continuous culture of oyster in the Pulicat lake.

In selecting the site, the weed infested areas also may be avoided. Both the rooted and floating algae in the lake are abundant which will affect the young larvae and spat by depleting the oxygen concentration of the lake water during the early morning hours. Sometimes, the weeds may settle on the cultch material itself and may undergo putrification, as a result of which there is the possibility of the mortality of the newly settled spat.

Boring and fouling organisms are fortunately found to be the minimum in the Pulicat lake. Barnacles may be said to be not so great a menace on the Pulicat oyster-beds. However, in May, Anomia and a few barnacles were found to occur along with the spat when the salinity was considerably high. Crabs like Scylla serrata play a role in killing the young oysters by preying upon them. The gastropods which usually prey upon oysters also were not found, since the lake is being inundated by freshwater during the North East monsoon which kills most of the marine organisms in the lake.

So far as the physical characteristics such as tides, waves and prevailing wind in the lake are concerned, the rack-culture and the hanging culture methods seem to be ideal for this lake. The nature of the bottom near the natural oyster-bed area is hard and hence it seems to be useful for the bottom sowing method also. However, preventive steps should be taken for safeguarding the culture

produce from the low saline waters, by establishing the oyster farm near the mouth of the lake, where the replenishing seawater is desirable.

At present there is a great demand for oysters in the Bombay market but still the oyster production in India is very limited. This demand can be met by culturing oysters in the shallow coastal areas and estuaries of India.

DISCUSSION

Salinity, temperature and other factors are of utmost importance to induce spawning, successful development of embryos to the veliger stage and to promote setting of oyster spat (Ranson, 1958; Loosanoff and Davis, 1952; Collier, 1965). Temperature is an important factor in inducing the American, the European and the New Zealand oysters to spawn in temperate waters. Stafford (1913), Nelson(1921, 1928a,b), Churchill (1920), Orton (1926,1937), Prytherch (1929), Galtsoff(1930, 1932, 1938) have shown that spawning occurs only when a critical temperature of the water is reached. Galtsoff (1964) reported successful spawning and setting of C. virginica occurred only above 20°C. Under tropical conditions as in India, the temperatures of the sea or backwaters is maintained high and uniform throughout the year and hence does not appear to influence

much in spawning. The fall in salinity during the North East monsoon on the contrary, is the chief stimulating factor in the spawning of the Madras oyster on the east coast backwaters of South India (Hornell, 1910, 1910a,1922; Bal, 1942 and Rao, 1951).

Investigations on the settlement of oyster-spat have been attempted by various workers viz., Hopkins(1931, 1936 & 1937), Gaarder (1932, 1933), Gaarder and Bjerkman (1934), Schaefer (1937), Miyazaki (1938), Butler (1955), Medcof (1955), Bonnot (1940), Korringa (1941), Cranfield (1968), Bardach et al., (1972), Wisely et al., (1979) and Sundaram and Thangavelu (1980). Settlement on different surfaces of the cultch has been investigated in different species of oysters of the two genera Ostrea and Crassostrea. Schaefer (1937), Hopkins (1935, 1937), Pomerat and Rainer (1942) and Cole and Knight-Jones (1949) have found a predominantly undersurface settlement in Crassostrea gigas, C. virginica, Ostrea lurida and O. edulis. Hopkins (1931) found the correlation between the periods of setting and the periods of high salinity in Ostrea virginica of Galveston Bay, Texas, and considered that the larvae depended on the salinity, either directly or indirectly, to develop to a setting stage. Gaarder (1932, 1933) and Gaarder and Bjerkman(1934) found that a salinity of 24‰ and above as essential and 30-35‰ as the optimum for the successful growth of the larvae of O. edulis.

Based on the present studies on the Pulicat Lake, the settlement of spat on tiles and shells was most intense especially during April/May for the three years of study and this was mainly attributed to the optimum salinity conditions prevailing for the larval growth and settlement. The intensity of spat settlement may be low or high, which is dependent on the freshwater influx brought in by the floods, during the rainy season. In the monsoon period, October/November, the intensity of spawning was considerably high but mortality of veliger larvae also was moderately high due to the prevalence of heavy silting and low saline waters in the lake. Losses of larvae during their pelagic life are obviously high but assessing the causes for this mortality is very difficult. Predation and dispersion are probably the major causes, although mortality due to disease has not been adequately evaluated. The relationship between larval behaviour and larval transportation are also poorly understood. During the summer months no such mortality of spat was observed.

Two types of spat collectors were used, one was irregular in shape and the other was flat, both of them seem to be effective cultch material for the procurement of spat. Andrews (1971) mentioned that the high salinity of the eastern shores of Virginia, Carolinas and Georgia exhibit intensive spat falls because of the moderately

high tidal amplitude. According to Pritchard (1952) both the James River and the Delaware Bay have low saline areas with high production of seed-oysters but the recruitment level was reduced due to increased salinity and disease.

Based on the studies on the Pulicat Lake, it was observed that the settlement of spat agrees with the views of Andrews (1970). Salinity was high in April/ May in both the years and the settlement of spat on cultch was also high during this period. In November, the poor settlement was observed due to prevalence of low saline conditions in the lake.

CHAPTER FOUR

BIOCHEMICAL COMPOSITION OF *CRASSOSTREA MADRASENSIS* FROM THE PULICAT LAKE.

Marine and estuarine bivalves form an important item of food for many coastal people, and bivalves are highly relished in some parts of the world. Since they are utilised for human consumption, information on their biochemical constituents during the different seasons of the year would be very valuable. Seasonal changes in the meatweight and biochemical composition of an animal are generally associated with its reproduction, storage and utilization of reserves.

The marine molluscs store large quantities of protein, fat and carbohydrate which render them highly nutritious as human food (Young,1928). Among the molluscs, oysters are considered as valuable food item, because they provide many of the mineral substances which are essential for a balanced diet.

Seasonal variations in the chemical composition of oysters have been reported Milroy (1907), Mitshell(1916), Russel (1923), Okazaki and Kobayashi (1929), Okazaki (1929), Sekine et al., (1929), Masumoto et al., (1934), Tully (1936), Hatanaka (1940), Humphrey (1941), Baker et al., (1941) Usuki and Koizumi (1954), Lee and Pepper (1956), Wentworth and Lewis (1958), Fieger et al. (1958), Durve and Bal (1961), Venkataraman and Chari (1951) and by Nagabhushanam and Bidadar (1978). The proximate composition of oysters has been carried out by Clarck and Clough (1926), Guarder and Sparck (1931), Masumoto; Masumoto and Hibino (1932, 1934), Coulron (1933), Galtsoff (1930b), Higashi (1936) and Lopez-Benito (1956). Galtsoff (1964) observed variations in the glycogen level from season to season in Crassostrea virginica. Quayle (1967) described the biochemical variation and the nutritive value of the Pacific oyster Crassostrea gigas. Biochemical analysis of other bivalve molluscs has been attempted by several investigators in varicus parts of the world, viz., Collip, (1921) in Mya; Dotterweich and Elssner,(1935) in Anodonta; Srinivasan (1963) in Martesia fragilis; Giese(1960) in Mytilus edulis and M. galloprovincialis; Ansell and Trevallion, (1967) in Tellina tenuis; Ansell and Lander(1967) in Mercenaria mercenaria; Ansell (1972) in Donax vittatus Ansell (1974a) in Abra alba; Ansell,(1974b) in Chlamys septemradiata, Ansell (1974c) in Nucula sulcata. Changes in the biochemical composition have also been reported for

Pinctada martensii (Ashikaga, 1948; Tanaka and Hatano,1952), Teredo pedicellata (Lane et al., 1952; Greenfield, 1953), Pecten jacobeus (Lopez-Benito, 1955), oysters and clams (Venkataraman and Chari, 1951), Martesia striata (Nagabushanam, 1961; Srinivasan, 1963; Srinivasan and Krishnaswamy 1964); Donax cuneatus (Rahman, 1965), Nausitoria hedleyi (Nair and Saraswathy, 1970), Patinopecten yessoensis (Takahashi and Mori, 1971), D. vittatus, Abra alba, Chlamys septemradiata, and Nucula sulcata (Ansell, 1972, 1974a,b,c), Mytilus edulis (De zwann and Zandee, 1972; Gabbott abd Bayne 1973; Dare and Edwards, 1975); Argopecten irradians(Estabrooks, 1973), Pecten maximus(Comely, 1974), Katelysia opima (Nagabhushanam and Mane, 1975c); Mytilus viridis (Mane and Nagabhushanam, 1973), Macoba balthica (Brukema and De Brunn, 1977), Paphia laterisulca (Nagabhushanam and Dhamne, 1977) and Villorita cyprinoides (Nair and Shynamma, 1975 and Ansari et al., 1981).

In early days, chemical composition of the entire animal was carried out by homogenising the whole animal. This sort of study was not considered as ideal in some cases where a particular constituent is of special interest and moreover there is a migration of nutrients from one tissue to another. For this purpose of fractional biochemical characterisation, the body of a mollusc therefore, is divided into its various body components.

Recent studies (Vasu and Giese, 1969; Giese et al., 1967; Lawrence and Giese, 1969; Ansell, 1974; Nagabhushanam and Mantale, 1972; Nagabhushanam and Mane, 1975 and Stephen 1980) have described the storage site for the nutrients in molluscs and their utilisation during breeding, starvation and such other stresses. The changes in the biochemical constituents are more profound in animals, that show annual reproductive cycles (Giese and Pearse,1974) and the information on the same is scanty in molluscs with semi-annual breeding cycles or lunar cycles (Giese,1969).

Earlier studies on the bichemical aspects of the Indian bivalves have been mainly concerned with the biochemical composition of the visceral mass of oysters, its seasonal changes in composition and its calorific values. The information regarding the different sexes, gonadal condition, biochemical changes during gametogenesis and environmental parameters could not be deduced properly from such studies as the animals were pooled and homogenised for analysis (Venkataraman and Chari, 1951; Durve and Bal, 1961; Rahman, 1965; Saraswathy and Nair, 1969; George and Nair, 1975; Sivankutty and Shynamma, 1975; Krishnakumari et al., 1977; Nagabhushanam and Mane, 1978; Nagabhushanam and Bidakar, 1978; Shafee, 1978; Ansari et al.,1981). The data thus obtained may have a limited use in a study of the relation of the animal to its

nutritive or reproductive status. To obtain more informative data Giese (1967) has suggested the analysis of different body components particularly to study the mobilization of nutrients during the period of gametogenesis. This sort of study has been conducted by Ansell (1964) in Mercenaria mercenaria; Giese (1967)in the black abalone, Haliotis carcherodii, Pinctada martensii, Tivela stultorum and Katherina tunicata; Reid (1969) in the horse clam, Tresus capax; Bayne and Thompson (1970) in Mytilus edulis; Nagabhushanam and Mantale (1972) in C. gryphoides; Gabbott and Bayne (1973), Bayne , (1975, 1976b) in Mytilus edulis; Mane and Nagabhushanam (1975) in Mytilus viridis Nagabhushanam and Mane (1973, 1974) in Katelysia opima; Thompson (1977) in Placopecten magellanicus; Stephen (1980) in Crassostrea madrasensis.

Though the work has been carried out by the above investigators in various bivalves in different places, the information on the biochemical aspects of the different body components of C. madrasensis lags far behind particularly at different stages of maturation of the gonad, seasonal variation, feeding intensity, different size-groups and different tissues of the oyster. The salinity of the Pulicat lake which ranges from the freshwater to the hypersaline condition, will its effect on the biochemical constituents and minerals of the oysters

also, in due course. Hence this study aims at the biochemical variations in five different body components viz., mantle, gill, adductor muscle, hepatopancreas and gonad of oysters, C. madrasensis with regard to their size, sex and gonadal condition, during the different seasons of the year.

MATERIAL AND METHODS

Samples were collected from the Pulicat lake once in a fortnight and after removing the epizoic growth on the shells, the length measurements and weight of the oysters were taken individually. After shucking, the condition of the gonad was ascertained and the individuals of the same gonadal condition were grouped together and used for removing their different body components like the mantle, gill, adductor muscle, hepatopancreas and gonad. The labial palp, since it is very small, it was combined with the gill, and hence in the text hereafter it will be mentioned compositely as gill only. Four different size groups i.e., 41-60 mm, 61-80 mm, 81-100 mm and 101-120 mm long oysters were considered for these biochemical studies. Samples were pooled and an average of nine individuals in each size group, with similar sex and gonadal conditions were used for the analysis of protein, fat and carbohydrate.

Each body component was weighed separately in a crucible of known weight, and then dried in an oven at 80°C to a constant weight. The water content was determined by substracting the dry weight from the wet weight. The percentage of water content was observed for all the four different size-groups but there was no statistically significant different between the water content of the various body components, in all the four size-groups. Hence the data concerning the water content was pooled together and taken into consideration for further studies.

PROTEIN

The protein content was estimated by the method of Gornoll et al., (1949)

Principle : Two carbamyl groups present in the protein molecules combine with copper and Potassium of the biuret reagent to form a blue coloured copper-potassium biuret compound. The colour formed is proportional to the amount of carbamyl groups present in the protein (Gornoll et al. 1949).

Reagents : 1) 1 N NaOH : Dissolved 4 gm of NaOH pellets in 100 ml of distilled water. 2) Biuret reagent : Dissolved 1.5 gm of cupric sulphate ($CUSO_4 5H_2O$) and 6 gm of sodium potassium tartarate in 500 ml of distilled water. Added 300 ml of 10 percent sodium hydroxide solution and this was made upto 1000 ml with distilled water.

Procedure : Standard preparation.

Dissolved 25 mg of bovine serum albumin crystals in a little amount of 1 N NaOH in a 5 ml standard flask and made upto 5 ml with 1 N NaOH. This serves as standard protein solution.

Known volume of protein solution containing known concentration of protein, was taken in a separate test-tube (for eg., 5 ml of stock solution contains 25 mg of protein, 0.2 ml of the stock solution contains 1 mg of protein, 0.6 ml of the stock solution contain 3 mg of protein; 0.8 ml contains 4 mg of protein, and so on) Made up these solutions to 2 ml individually with 1 N NaOH. Afterwards 8 ml of Biuret reagent was added, mixed well and allowed to stand at room temperature. Blank was set up having 2 ml of 1 N NaOH and 8 ml of Biuret reagent. After 30 minutes measured the optical density at 540 nm in a spectrophotometer. The concentration of protein was plotted in X axis and optical density at Y axis and drawn the slope.

Estimation of protein : 5 mg of tissue was taken in a test tube and deproteinised by adding 1 ml of 80 percent ethanol. If the tissue was not dissolved it was kept in boiling water bath till it was dissolved. Centrifuged at 3000 rpm for 5 minutes, decanted the supernatant and added 2 ml of 1 N NaOH to dissolve the precipitate. After 10 minutes 8 ml

of the Biuret reagent was added, mixed well and allowed it to stand at room temperature. Set up the blank simultaneously having 2 ml of 1 N NaOH and 8 ml of the Biuret reagent. After 10 minutes, measured the optical density in a spectrophotometer and referred the O.D. value to the standard graph and found out the protein concentration.

CARBOHYDRATE

Alkali extractable carbohydrate was estimated by determining the amount of glucose present in the alkali digest of the tissue (Morals et al., 1973).

Reagents :

1. 30 percent solution of Potassium hydroxide
2. Absolute alcohol
3. Anthrone reagent : 200 mg of anthrone(Analar) was dissolved in 100 ml of conc H_2SO_4. This was prepared just before use.

Procedure : 10 gm of tissue from each body component was subjected to alkali digestion by treatment with 3 ml of 30 percent potassium hydroxide solution. The tubes were heated in a boiling water bath for 20 minutes, cooled and centrifuged. From this 0.1 ml of the solution was taken and 5 ml of Anthrone reagent was added. The tubes were shaken well, covered with marble caps and heated in a boiling water bath for 20 minutes. After cooling absorbance was read at 640 nm against the blank containing water and was treated

in a similar manner as test. Standard solution of glucose containing 25-100 micrograms, was also subjected to the same procedure. The carbohydrate values were expressed as percentage of dry weight tissue.

FAT

The total lipid content was extracted by the method of Folch et al., (1957) using Chloroform : Methanol, in the ratio 2:1. A weighed amount of tissue was extracted with Chloroform : methanol mixture, in tuflon homogeniser. The extraction was repeated thrice with fresh aliquots of chloroform : methanol. The lipid extracts were transferred to separating funnels containing 2 ml of physiological saline and left overnight, after which the lipid extracts were drained into weighed beakers and allowed to dry to constant weight. The total lipid content was calculated and expressed as percentage of dry weight tissue.

RESULTS

SEASONAL VARIATIONS IN THE BIOCHEMICAL LEVELS

PROTEIN LEVEL

The protein content in different body components of dif. size groups of oysters is pooled together and given in Fig. 16. The protein level in all body components of C. madrasensis lies between the range of 22.5% to 78.5% and 21.5% to

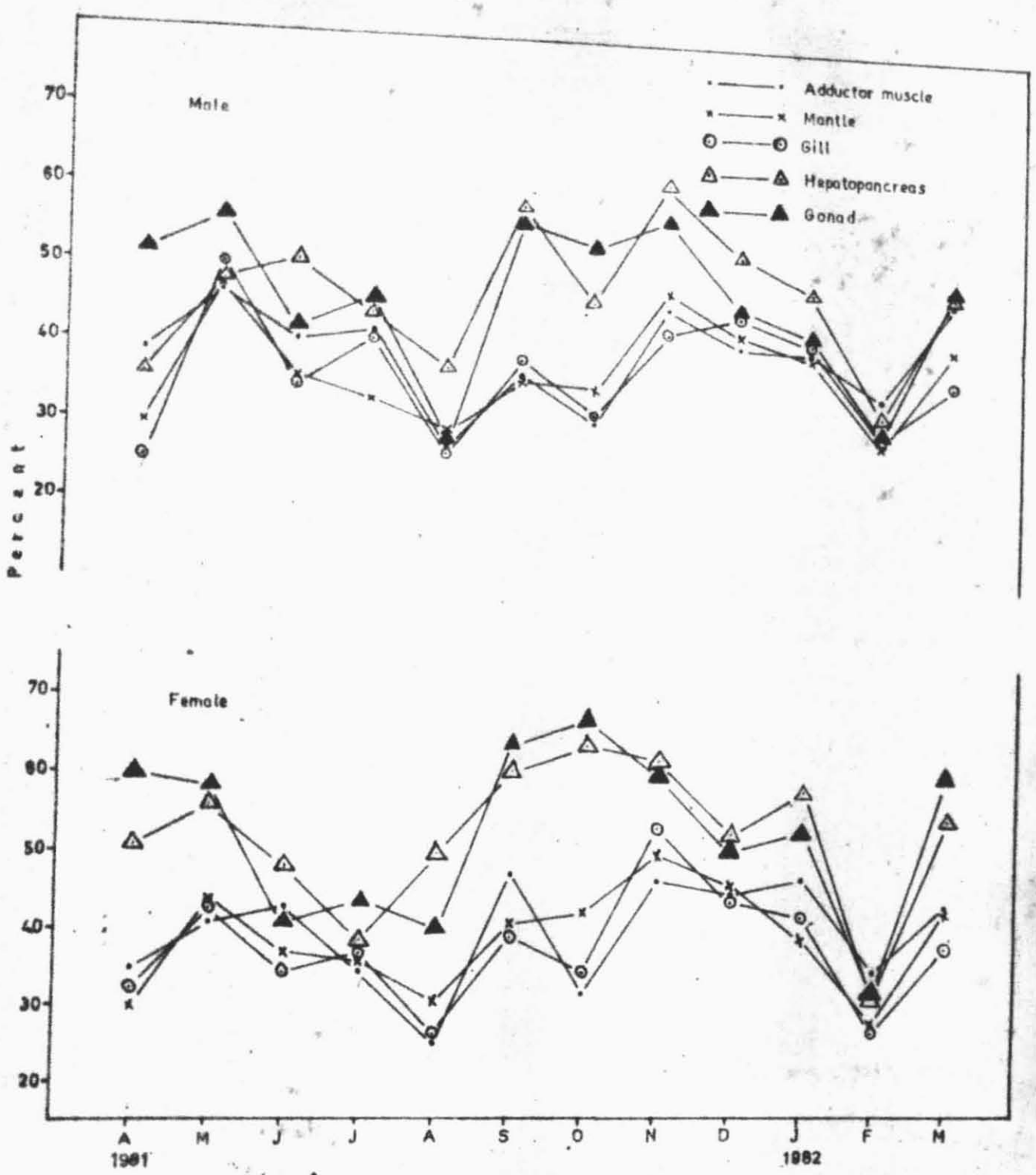


Fig. 16 Protein level of the body components of C. madrasensis during April 1981 — March 1982.

66% for females and males respectively. The maximum values were found in both the hepatopancreas and gonad, and it was ranging between 30.8% and 78.5% for hepatopancreas and 30.4% and 72.5% for gonad of all females. Correspondingly, the percentage of protein for males was ranging between 29.6% and 65% in the hepatopancreas and 28% to 66% in the gonad. Mantle, gill and adductor muscle showed the lowest protein content in both the sexes. Even though the protein content was less in the mantle, gill and adductor muscle, yet they also show remarkable fluctuations during the different months of the year. The percentage of protein of all the body components of different size-groups was pooled together and plotted in Fig. 16 to show the seasonal variations. The average protein values of female oysters showed slightly higher values when compared to the males, during the different periods of the year.

The protein in different components has shown two prominent peaks. The primary peak was during October-November and the secondary peak was during April-May. There was peak observed during the first week of May indicating the full maturation of the reproductive elements in both the male and female oysters, and there was a fall in concentration of protein in the subsequent month indicating the spawning of oysters. Thw lowest level of protein was observed in all the body components

during the month of June, but hepatopancreas also showed 48% and 50.6% protein in both females and males which was always higher than that of the other body components. In the month of July, there was a further reduction in the quantity of protein in all the body components of both males and females. A possible explanation for the decrease in protein level is the increase in carbohydrate level which occurs at the end of spawning, and slowly decreases till the gametes mature in the gonad. During the month of August, a considerable hike in the protein level was once again observed in the hepatopancreas. This hike was continued during the month of September also. Simultaneously, there was a very active gametogenesis occurring during this period coinciding with the high increase in the level of protein in both the male and female oysters. The level of protein reached a peak during October-November in the gonad as well as in the hepatopancreas, when the oysters were gravid, which presumably reflects the high protein content of the maturing gonads. Since the gonad of the oyster is always in close contact with the digestive gland, whatever changes occur in the hepatopancreas, they are reflected immediately in the gonad of the oyster also. Mantle also showed very wide fluctuations as the gonad and hepatopancreas. The highest values were observed during the ripe condition of the gonad and the lowest

concentration of protein was observed during the post-spawning period of both the sexes of oysters.

The percentage of protein in both females and males was observed to go down slightly, during October 1981. This may be probably due to the very low feeding intensity also, resulting in the slow maturation of the gonad. Also, it shows up only in certain parts of the body, but not in the gonad and hepatopancreas. There was a definite decline in the protein concentration of the gonad after the extrusion of the reproductive elements. There was a further decline in the protein level during December and January, and right upto the resting stage of oysters.

Thus the highest protein level coincided with the mature stage of oysters, and the lowest level with the spent stage. The level of protein rises again at the beginning of the active feeding of oysters during January, with increasing salinity.

FAT LEVEL

The fat content of all the body components showed seasonal variations in relation to the reproductive cycle (Fig. 17). The fat content was found to be high in the gonad at the beginning of the summer, reaching its peak during the first week of May, as a result of the sedond

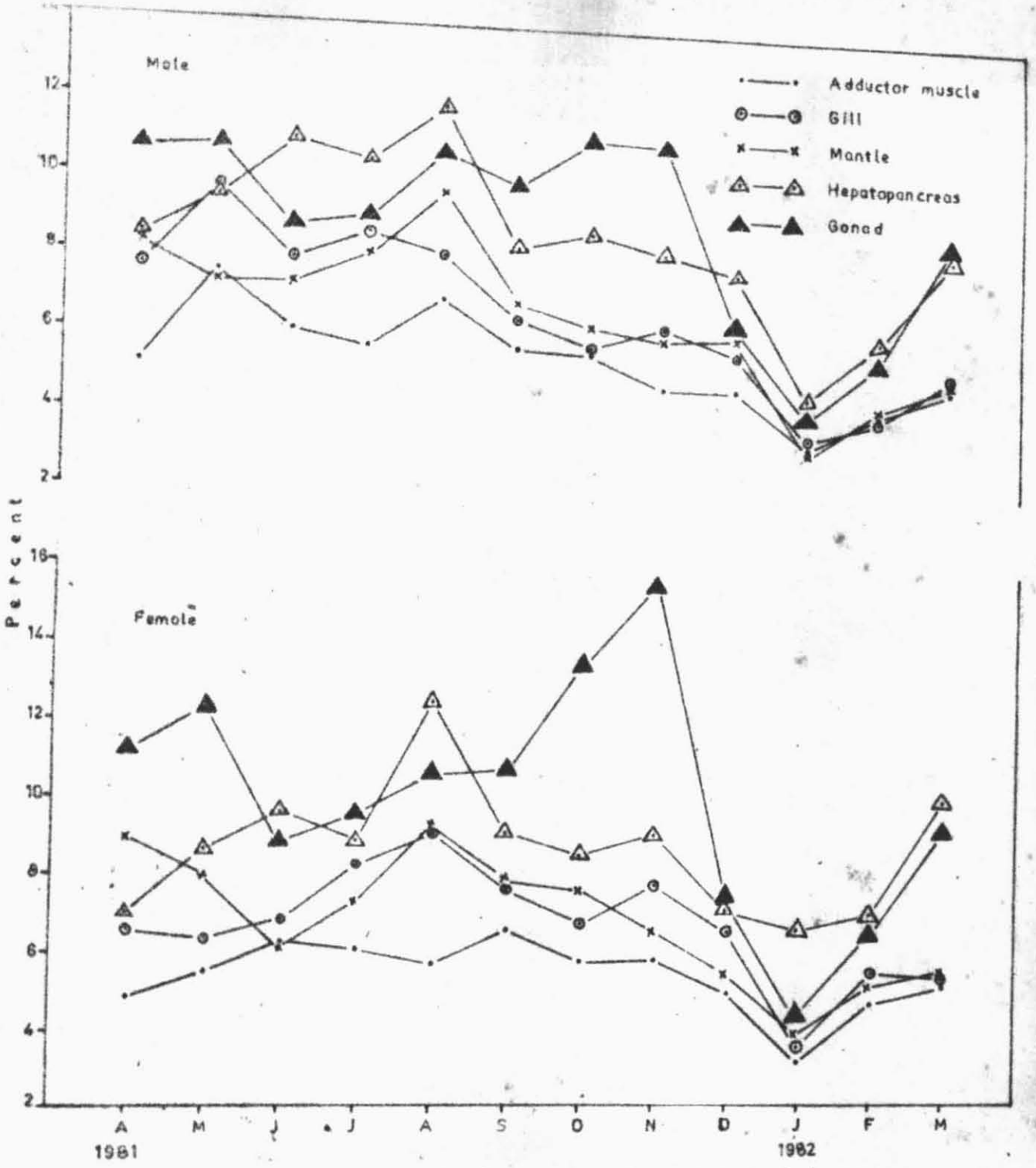


Fig. 17 Fat level of the body components of C. madrasensis during April 1981 — March 1982.

maturation period of the gonads. It declines thereafter and reaches the lowest level in the month of June. The hepatopancreas, on the other hand, showed a reciprocal relationship, increased from a lower level to a higher level in June. There were feeble fluctuations in the fat content of mantle and gill during this period. There was a slight increase in the fat level of the gonad during the month of July and the same trend was observed in the subsequent month also. There was a slow decline in the fat level of the gonad during September, but it was found to increase very steeply from September to November in the females but a very slow progress was observed correspondingly in the case of the male oysters. Thus there was a very high concentration of fat observed in females than in the males, during the peak period of gametogenesis. From August to January, the fat content of the hepatopancreas showed a declining trend. There was a steep fall in the fat content of the gonad during November indicating the spawning of oysters. During the post-monsoon season again there was a hike in the fat level in all the body components as a result of rematuration of the gonad for the second breeding season.

The fat content of the body components showed greater correlation with the reproductive cycle were the gonad and hepatopancreas only. The fat content of the gonad rises

and attains a peak in May and November and drops to a minimum level in the subsequent months, whereas in the hepatopancreas it was found to be maximum in August and in March, declining during May and December. During this study reciprocal relationship between the hepatopancreas and the gonad with regard to their fat content was observed. Fat forms the reserve nutrient in the hepatopancreas. Mantle, which is an intermediate storage organ accumulates fat during the high feeding intensity only, and this fat is supplied to the gonad at the time of formation of gametes.

CARBOHYDRATE LEVEL

The seasonal variations in the glycogen content of the different body components of the oysters are illustrated in Fig. 18. In general, it showed variations with the breeding pattern and the maturation of the gonad. The carbohydrate was at a low level in May and it was noted to increase intensiverly from May to July in all the body components of both the males and females. During July, the carbohydrate content was at a maximum level both in the hepatopancreas and in the gonad, more or less in equal quantities. During the pre-monsoon period when the gonads showed the peak period of active gametogenesis, the carbohydrate level was found to decrease gradually. This slope

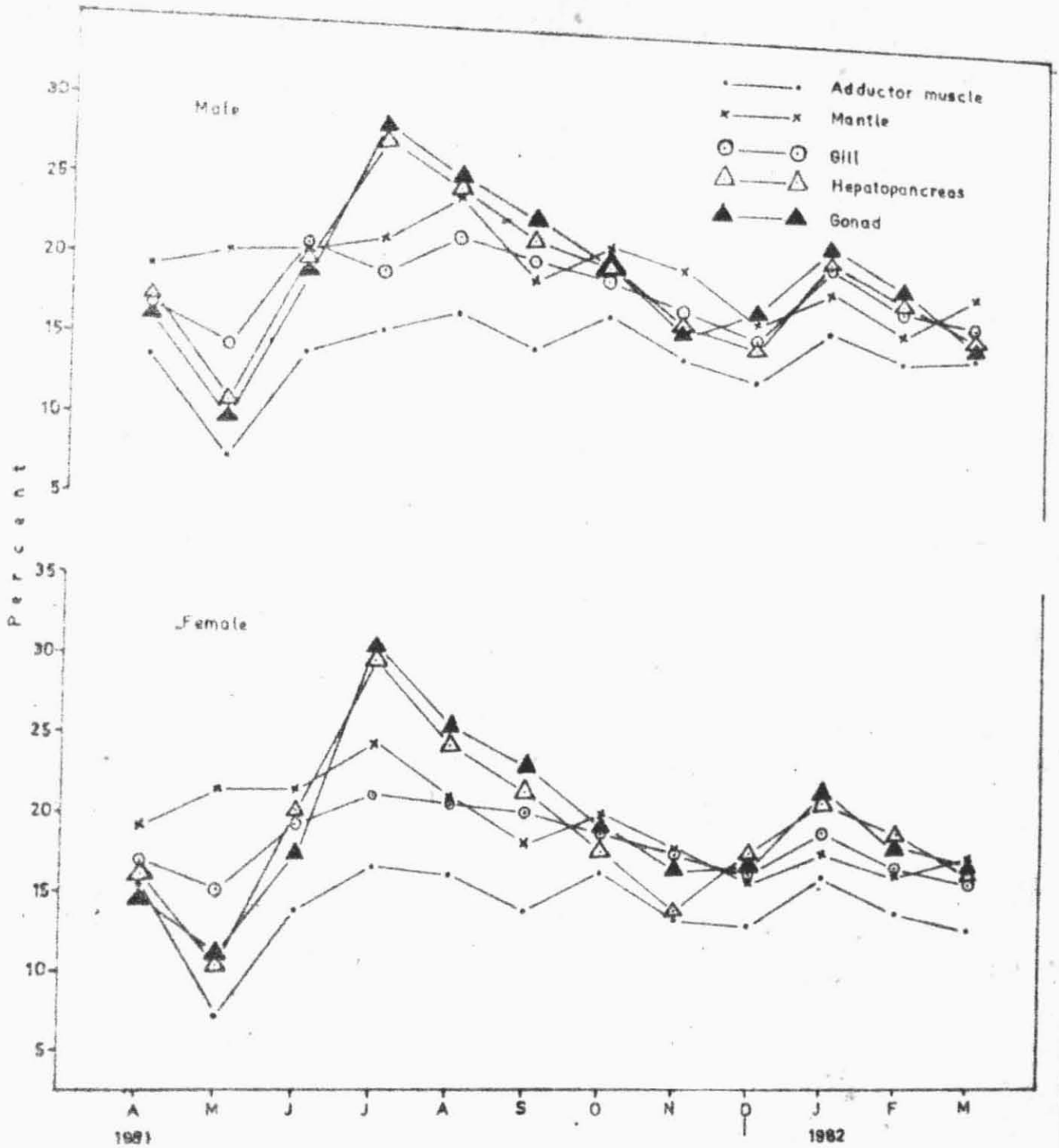


Fig. 18 Carbohydrate level of the body components of C. madrasensis during April 1981—March 1982.

in glycogen was continued till November when the oysters were noticed in fully ripe condition. Thus the gonads show the least carbohydrate storage when mature gametes are present, suggesting a total utilization of the carbohydrate reserves.

Glycogen is the reserve material, and it is stored primarily in the connective tissue of the mantle. During the rapid proliferation of sex cells the reserve supply from the mantle is used and by the end of the reproductive cycle the amount of glycogen is at its minimum level and by then the mantle is reduced from a thick layer to a thin transparent membrane. Thus the carbohydrate content of the mantle showed a seasonal cycle. Immediately after spawning, the glycogen level was found to increase gradually in all the body components and attains a second peak during January, preceding the second peak of maturation during the summer months. The secondary peak of carbohydrate observed in the case of oysters seem to be less prominent than the primary one, and after the second peak again, there was a slight reduction of glycogen in the subsequent months.

The carbohydrate level is high during the early stages of maturation and decreases after the gametes have developed. The protein level in the gonad, on the other hand, is found to be high when the ripe gametes are present, and declines after their release when there is a subsequent

increase in the carbohydrate level. The decrease in carbohydrate level with the corresponding increase in the protein level could perhaps be due to the conversion of carbohydrates into protein, during gametogenesis.

BIOCHEMISTRY OF THE BODY COMPONENTS

The level of protein in all the body components is highly varying from 22.5% to 78.5% (Table 14 & 15). Of all the body components, gonad and hepatopancreas showed remarkable fluctuations during the reproductive cycle of the oysters. The protein values were highest ranging from 30.4% to 72.5% in the gonad of the 41-60 mm size group of oysters. The lowest value was observed in February because of a low intensity of feeding and the highest value was in October, with the gravid condition of the gonad. The hepatopancreas also showed the highest variation in the protein level, between 30.8% and 78.5% in the case of females and 29.6% to 65% in males.

The lowest level of protein was noted in the mantle, adductor muscle and gill, The fluctuations in these body components observed in different months were feeble when compared to the distinct peaks in the hepatopancreas and in gonad, as seen from fig.16. The highest protein values coincided with the mature stage of the animal and

TABLE - 14

PERCENTAGE OF PROTEIN IN THE BODY COMPONENTS OF C. MADRASENSIS DURING APRIL 1981 - MARCH 1982; EACH VALUE REPRESNETS THE AVERAGE ESTIMATE OF 5 TO 6 SAMPLES (MEAN ± S.D.)

SIZE GROUP (MM)	MONTH & YEAR	BODY COMPONENTS										
		FEMALE					MALE					
		MANTLE	GILL	ADDUCTOR MUSCLE	HEPATOPAN-EREAS	GONAD	MANTLE	GILL	ADDUCTOR MUSCLE	HEPATOPAN-EREAS	GONAD
101-120	APRIL 1981	30.0 ± 2.31	36.0 ± 3.27	41.0 ± 6.83	55.0 ± 6.83	63.5 ± 5.26	29.0 ± 2.00	25.0 ± 6.00	38.0 ± 2.31	42.0 ± 1.63	55.0 ± 6.00
	MAY	41.0 ± 5.03	40.0 ± 1.63	54.0 ± 2.31	64.0 ± 3.27	71.0 ± 6.83	43.5 ± 3.42	35.5 ± 2.52	32.5 ± 3.42	43.0 ± 3.83	56.5 ± 3.00
	JUNE	34.8 ± 2.68	32.0 ± 2.50	44.0 ± 3.74	43.6 ± 3.85	39.6 ± 2.61	36.8 ± 5.22	36.4 ± 2.97	45.2 ± 4.82	54.0 ± 2.83	45.0 ± 2.19
	JULY	35.0 ± 2.00	31.5 ± 2.52	33.5 ± 1.91	34.5 ± 1.63	36.0 ± 3.65	33.0 ± 3.83	31.0 ± 3.83	39.5 ± 3.42	39.5 ± 1.00	43.0 ± 3.83
	AUG.	28.5 ± 1.91	27.0 ± 2.00	22.5 ± 1.91	45.5 ± 3.78	34.5 ± 3.00	31.0 ± 2.00	33.5 ± 3.00	27.5 ± 3.83	39.5 ± 1.91	29.5 ± 3.78
	SEP.	47.0 ± 2.00	46.5 ± 2.49	35.0 ± 3.80	63.0 ± 2.00	68.5 ± 2.50	31.0 ± 3.82	37.0 ± 3.83	32.5 ± 0.00	54.5 ± 5.00	55.0 ± 6.00
	OCT.	49.5 ± 4.43	35.0 ± 2.58	30.0 ± 2.31	67.0 ± 1.15	68.5 ± 1.91	32.0 ± 3.27	30.5 ± 1.91	33.5 ± 4.43	40.0 ± 5.42	42.0 ± 4.90
	NOV.	54.4 ± 1.67	47.2 ± 1.79	45.2 ± 3.90	63.6 ± 2.97	61.6 ± 2.19	52.4 ± 3.29	43.6 ± 3.84	46.4 ± 6.16	62.4 ± 5.18	62.4 ± 3.78
	DEC.	46.4 ± 1.67	41.2 ± 4.38	43.6 ± 2.97	59.6 ± 2.61	53.6 ± 2.61	45.2 ± 1.79	44.8 ± 4.98	42.0 ± 2.00	57.2 ± 1.79	45.6 ± 2.19
	JAN. 1982	37.6 ± 5.40	40.8 ± 4.40	45.2 ± 8.20	58.0 ± 7.48	44.0 ± 0.20	40.4 ± 2.97	40.4 ± 6.69	41.6 ± 4.56	53.2 ± 10.45	44.0 ± 9.38
	FEB.	29.6 ± 3.58	28.0 ± 4.00	39.2 ± 3.38	30.8 ± 3.90	23.2 ± 6.57	31.2 ± 1.79	28.0 ± 4.00	39.2 ± 5.22	32.8 ± 1.79	26.8 ± 7.16
	MAR.	45.6 ± 6.54	37.6 ± 2.19	41.2 ± 3.90	56.8 ± 4.38	61.2 ± 3.35	46.0 ± 3.74	35.2 ± 1.91	45.2 ± 2.68	55.2 ± 1.79	51.2 ± 6.57
81-100	APRIL 1981	31.0 ± 3.83	29.5 ± 4.43	38.0 ± 2.31	57.5 ± 1.91	61.0 ± 4.76	33.0 ± 5.03	29.0 ± 3.83	34.0 ± 2.83	35.0 ± 2.00	47.0 ± 3.83
	MAY	51.0 ± 3.46	42.5 ± 3.00	40.0 ± 5.66	62.0 ± 5.16	70.0 ± 4.00	42.0 ± 7.66	54.0 ± 10.06	49.0 ± 3.83	38.0 ± 4.43	51.0 ± 8.25
	JUNE	39.2 ± 4.15	38.8 ± 3.35	42.0 ± 4.00	49.6 ± 4.77	34.4 ± 3.85	37.6 ± 2.19	39.6 ± 2.97	36.4 ± 2.61	52.4 ± 2.97	44.0 ± 2.83
	JULY	33.0 ± 3.383	34.0 ± 4.00	32.5 ± 2.52	35.0 ± 3.46	52.5 ± 2.52	30.5 ± 4.43	32.0 ± 1.63	42.0 ± 2.31	44.0 ± 4.32	41.5 ± 2.52
	AUG.	27.5 ± 3.41	24.0 ± 3.27	28.5 ± 4.12	45.0 ± 4.76	41.5 ± 3.78	31.0 ± 2.00	28.5 ± 4.12	26.0 ± 3.65	36.0 ± 2.82	28.0 ± 4.32
	SEP.	40.5 ± 4.12	40.0 ± 4.65	58.0 ± 5.16	58.5 ± 7.55	67.5 ± 3.4	33.5 ± 1.90	34.0 ± 2.31	37.5 ± 5.00	60.0 ± 4.60	60.0 ± 3.48
	OCT.	42.5 ± 5.00	37.5 ± 1.91	29.0 ± 5.00	63.5 ± 5.26	63.0 ± 2.00	33.5 ± 5.00	31.5 ± 5.26	29.0 ± 2.00	47.5 ± 4.73	47.0 ± 4.76
	NOV.	49.2 ± 1.79	57.2 ± 1.79	47.2 ± 1.79	67.6 ± 5.90	61.0 ± 3.83	48.0 ± 2.83	42.8 ± 4.38	48.0 ± 7.67	64.4 ± 2.97	52.0 ± 2.82
	DEC.	48.4 ± 3.58	42.8 ± 3.35	44.0 ± 5.48	54.0 ± 8.72	54.4 ± 3.58	43.6 ± 4.34	42.4 ± 4.34	40.4 ± 4.56	46.8 ± 2.28	41.2 ± 4.82
	JAN. 1982	45.3 ± 6.58	42.4 ± 7.80	45.6 ± 6.69	44.8 ± 3.35	54.0 ± 2.83	46.4 ± 3.85	44.8 ± 3.9	39.2 ± 3.35	55.2 ± 8.67	38.8 ± 5.22
	FEB.	34.4 ± 3.58	22.4 ± 2.19	38.4 ± 2.19	32.0 ± 2.83	39.2 ± 3.35	32.0 ± 5.66	27.2 ± 3.35	32.8 ± 1.75	33.6 ± 2.19	29.6 ± 6.69
	MAR.	41.6 ± 7.27	41.6 ± 3.58	44.8 ± 3.03	58.4 ± 2.19	63.3 ± 2.28	42.4 ± 5.90	42.4 ± 9.21	37.2 ± 4.38	47.2 ± 3.35	47.2 ± 3.35

TABLE - 15

PERCENTAGE OF PROTEIN IN THE BODY COMPONENTS OF C. MADRASENSIS DURING APRIL 1981 - MARCH 1982; EACH VALUE REPRESENTS THE AVERAGE ESTIMATE OF 5 TO 6 SAMPLES (MEAN ± S.D.)

SIZE GROUP (MM)	MONTH AND YEAR	BODY COMPONENTS									
		FEMALE					MALE				
		MANTLE	GILL	ADDUCTOR MUSCLE	HEPATOPAN-EREAS	GONAD	MANTLE	GILL	ADDUCTOR MUSCLE	HEPATOPAN-EREAS	GONAD
	1981										
61.80	APRIL	26.0 ± 4.00	31.0 ± 2.00	29.0 ± 3.83	45.0 ± 3.83	57.5 ± 3.00	23.0 ± 5.03	24.0 ± 5.66	29.0 ± 6.00	35.0 ± 5.03	50.0 ± 7.12
	MAY	48.0 ± 3.27	52.5 ± 2.52	35.[illegible] ± 3.83	44.0 ± 3.42	46.0 ± 6.93	50.0 ± 2.00	53.0 ± 1.15	58.0 ± 5.16	53.0 ± 7.57	58.0 ± 5.16
	[illegible]	[illegible] ± 2.70	[illegible] ± 1.67	[illegible] ± [illegible]	49.2 ± 2.68	48.4 ± 2.97	34.[illegible] ± 3.39	31.6 ± 4.56	42.0 ± 2.00	50.8 ± 2.28	40.4 ± 2.97
	JULY	31.0 ± 3.46	39.5 ± 2.[illegible]	39.0 ± 2.00	41.5 ± 1.[illegible]	48.[illegible] ± 6.53	34.5 ± 4.43	36.5 ± 1.00	41.0 ± 3.83	49.5 ± 5.97	52.[illegible] ± 4.62
	AUG.	33.0 ± 2.00	30.0 ± 2.31	[illegible] ± 1.91	50.0[illegible] ± 4.00	45.0 ± 6.80	24.5 ± 1.00	21.5 ± 1.91	26.5 ± 1.00	30.5 ± 1.91	28.5 ± 1.00
	SEP.	41.0 ± 2.58	35.0 ± 3.83	[illegible] ± 6.4	[illegible] ± 8.25	62.0 ± 5.16	37.0 ± 3.83	47.0 ± 2.00	39.5 ± [illegible].00	65.0 ± 2.58	56.0 ± 1.63
	OCT.	38.5 ± 1.91	34.5 ± 3.79	32.0 ± 5.66	57.0 ±10.5	58.0 ± 8.00	34.0 ± 2.31	33.5 ± 3.00	32.0 ± 4.32	48.0 ± 3.29	56.5 ± 2.52
	NOV.	32.0 ± 7.48	61.2 ± 3.35	47.2 ± 7.92	[illegible] ± 9.21	70.0 ± 3.16	47.2 ± 2.28	48.8 ± 3.03	44.4 ± 6.39	63.6 ± 2.19	66.0 ± 8.94
	DEC.	[illegible].4 ± 2.[illegible]	44.8 ± 2.28	[illegible] ± 3.35	50.0 ± 1.41	47.6 ± 1.67	42.8 ± 3.90	46.8 ± 5.93	40.4 ± 7.27	54.8 ± 3.35	47.6 ± 5.37
	JAN. 1982	43.2 ± 2.[illegible]	44.4 ± 2.97	46.8 ± 2.68	63.2 ± 4.38	59.2 ± 4.38	38.4 ± 5.37	40.0 ± 4.00	39.2 ± 5.22	48.0 ± 6.32	40.8 ± 1.57
	FEB.	24.8 ± 1.79	28.8 ± 3.35	35.2 ± 3.35	32.0 ± 2.83	30.4 ± 3.58	23.6 ± 4.98	28.0 ± 2.83	36.4 ± 3.58	33.6 ± 3.58	31.2 ± 4.38
	MAR.	42.4 ± 6.07	37.6 ± 3.58	40.8 ± 6.57	54.8 ± 4.[illegible]	60.4 ± 2.19	42.4 ± 4.56	35.2 ± 3.35	36.9 ± 2.97	47.2 ± 7.69	[illegible] ± 8.79
41.60	APRIL 1981	32.0 ± 2.60	33.0 ± 1.63	32.0 ± 5.66	44.8 ± 3.42	57.0 ±10.5	34.0 ± 6.93	22.0 ± 2.31	46.[illegible] ± 2.31	35.0 ± 3.46	56.0 ± 3.27
	MAY	36.[illegible] ± 3.42	37.5 ± 1.91	35.5 ± 1.91	55.5 ± 2.52	48.0 ± 2.31	52.[illegible] ± 5.74	58.5 ± 3.79	50.0 ± 2.83	61.0 ± 3.83	60.5 ± 2.52
	JUNE	37.2 ± 3.90	33.2 ± 1.79	36.8 ± 4.15	49.6 ± 5.90	43.2 ± 1.10	32.[illegible] ± 2.83	35.2 ± 3.35	40.4 ± 4.56	45.2 ± 3.90	39.2 ± 3.35
	JULY	44.5 ± 1.00	42.0 ± 5.16	35.[illegible] ± 4.12	42.5 ± 1.91	37.5 ± 1.91	36.0 ± 3.27	40.5 ± 3.42	43.0 ± 3.83	44.5 ± 2.52	47.5 ± 2.52
	AUG.	36.5 ± 1.00	24.5 ± 2.51	25.5 ± 1.91	62.0 ± 2.83	39.5 ± [illegible].00	29.5 ± 1.91	22.5 ± 1.91	29.5 ± 3.00	44.5 ± 4.43	24.[illegible] ± 3.42
	SEP.	35.0 ± 2.58	36.5 ± 3.42	34.5 ± 3.79	57.5 ± 1.91	58.5 ± 2.78	42.5 ± 1.91	36.5 ± 3.42	35.0 ± 3.82	57.[illegible] ± 3.00	57.5 ± 5.0[illegible]
	OCT.	38.5 ± 4.43	32.5 ± 2.52	37.5 ± 1.91	78.5 ± 1.00	72.5 ± 4.43	43.0 ± 5.00	30.6 ± 2.21	30.0 ± 2.21	49.5 ± 7.54	54.0 ± 7.65
	NOV.	45.6 ± 2.61	49.2 ± 1.79	46.8 ± 1.79	62.8 ± 3.03	50.8 ± 3.63	44.4 ± 3.58	45.6 ± 6.07	44.8 ± 6.51	58.4 ± 9.6[illegible]	48.0 ± 9.38
	DEC.	44.4 ± 2.1[illegible]	48.2 ± 5.40	40.8 ± 5.02	46.4 ± 2.61	38.8 ± 2.28	39.6 ± 3.58	46.4 ± 3.58	42.0 ± 1.41	55.2 ± 3.35	46.8 ± 1.79
	JAN. 1982	32.8 ± 3.35	42.0 ± 4.47	50.4 ± 6.07	68.4 ± 3.58	55.0 ± 8.67	36.4 ± 2.97	42.8 ± 3.35	44.6 ± 3.35	38.4 ± 4.56	4[illegible] ± 6.87
	FEB.	22.4 ± 3.58	29.6 ± 2.19	27.2 ± 4.38	31.2 ± 1.79	30.4 ± 6.07	27.2 ± 4.38	32.8 ± 4.38	33.6 ± 4.56	29.6 ± 3.58	2[illegible] ± 8.00
	MAR.	40.4 ± 6.69	[illegible].0 ± 1.41	43.6 ± 4.98	50.4 ± 2.61	56.8 ± 3.35	35.6 ± 2.97	34.5 ± 1.79	48.4 ± 4.10	45.6 ± 4.56	44.4 ± 2.97

the lowest values were observed during the resting period and during the low feeding periods.

The only body component which was found to contain very high or low level of fat was the gonad which showed 15.09% of fat in females and 11.24% of fat in males(Table 16 & 17). The highest fat content of hepatopancreas was observed in the month of August, declining thereafter. The only body component which showed biochemical correlation with the reproductive cycle was the gonad. Fat forms the reserve nutrient in the hepatopancreas, showing its peak during the month of August and this stored material was supplied to the gonad during the subsequent period of gametogenesis. The mantle also showed similar trend as the hepatopancreas, showing its maximum value during August and declining in the subsequent months indicating that this body component serves as the secondary storage organ for fat. The gill also showed more or less similar fluctuation as the mantle especially in the females, but in the male the fluctuation was very significant. The lowest level of fat was observed in the adductor muscle with no apparent pattern of fluctuation.

In the present study, the highest value of carbohydrate in all the body components was observed in July, and the lowest in December (Table.18 & 19), with a short period of resting phase, after which the glycogen value

TABLE - 16

PERCENTAGE OF FAT IN THE BODY COMPONENTS OF C. MADRASENSIS DURING APRIL 1981 - MARCH 1982;

EACH VALUE REPRESENTS THE AVERAGE ESTIMATE OF 5 SAMPLES (MEAN ± S.D.)

SIZE GROUP (MM)	MONTH & YEAR	BODY COMPONENTS									
		FEMALE					MALE				
		MANTLE	GILL	ADDUCTOR MUSCLE	HEPATOPAN-EREAS	GONAD	MANTLE	GILL	ADDUCTOR MUSCLE	HEPATOPAN-EREAS	GONAD
101-120	APRIL 1981	9.37 ± 0.57	7.80 ± 0.53	5.17 ± 0.21	7.70 ± 0.36	13.17 ± 0.64	9.06 ± 0.40	8.23 ± 0.68	6.00 ± 0.98	8.73 ± 0.31	10.67 ± 0.81
	MAY	7.57 ± 0.45	7.63 ± 0.64	6.13 ± 0.12	6.90 ± 0.56	11.30 ± 1.10	6.93 ± 0.95	9.77 ± 1.07	7.83 ± 2.34	9.30 ± 0.92	10.80 ± 0.60
	JUNE	5.57 ± 0.65	7.47 ± 0.55	6.57 ± .07	9.70 ± 3.08	8.70 ± 0.91	7.43 ± 0.68	6.97 ± 1.00	5.60 ± 0.61	6.70 ± 0.36	6.70 ± 1.14
	JULY	4.93 ± 0.31	7.10 ± 0.70	5.77 ± 0.61	7.67 ± 1.24	7.93 ± 1.92	9.10 ± 0.82	7.8 ± 1.06	6.00 ± 1.11	10.47 ± 1.12	6.40 ± 0.70
	AUG.	8.37 ± 0.35	7.67 ± 0.58	4.30 ± 0.61	10.40 ± 0.53	9.53 ± 0.38	10.07 ± 0.90	7.03 ± 1.05	6.30 ± 0.82	12.30 ± 3.52	8.20 ± 1.57
	SEP.	9.07 ± 0.12	8.60 ± 1.40	5.57 ± 0.15	6.50 ± 0.36	12.03 ± 0.65	8.47 ± 1.19	7.17 ± 0.21	6.83 ± 0.57	9.17 ± 0.55	11.27 ± 0.70
	OCT.	7.43 ± 1.47	7.47 ± 0.50	6.3 ± 1.44	9.13 ± 1.22	14.93 ± 1.40	6.77 ± 1.10	4.8 ± 0.56	5.47 ± 0.64	8.63 ± 0.55	11.73 ± 0.76
	NOV.	6.67 ± 0.67	8.73 ± 0.64	5.93 ± 0.95	7.17 ± 1.70	17.73 ± 1.22	6.13 ± 0.81	6.33 ± 0.87	4.80 ± 0.62	9.06 ± 0.95	11.47 ± 0.50
	DEC.	5.27 ± 0.95	7.50 ± 1.31	5.40 ± 0.79	6.37 ± 0.47	9.37 ± 1.18	4.50 ± 1.23	5.00 ± 0.35	4.90 ± 0.17	4.90 ± 1.00	5.43 ± 1.06
	JAN. 1982	4.17 ± 0.38	3.73 ± 0.15	3.40 ± 0.20	5.20 ± 0.36	3.67 ± 0.21	3.37 ± 0.06	3.73 ± 0.31	3.70 ± 0.61	3.73 ± 0.15	3.63 ± 0.35
	FEB.	4.70 ± 0.50	4.77 ± 0.25	4.23 ± 0.32	5.03 ± 0.80	6.13 ± 1.00	4.03 ± 0.91	3.53 ± 0.40	3.17 ± 0.15	5.10 ± 1.50	4.20 ± 0.72
	MAR.	4.93 ± 0.38	5.53 ± 0.42	4.70 ± 0.44	9.07 ± 1.02	8.77 ± 0.32	3.43 ± 0.40	4.63 ± 0.15	4.95 ± 0.31	8.77 ± 0.51	7.80 ± 0.70
81-100	APRIL 1981	7.43 ± 0.45	6.50 ± 0.38	4.77 ± 0.49	6.87 ± 0.45	9.10 ± 0.62	10.37 ± 1.48	8.80 ± 1.06	5.83 ± 0.47	9.03 ± 0.95	10.23 ± 0.97
	MAY	7.97 ± 0.71	7.43 ± 1.07	6.8 ± 0.72	11.63 ± 1.18	11.37 ± 1.65	8.17 ± 1.02	10.87 ± 1.21	7.73 ± 0.36	8.90 ± 0.20	12.24 ± 0.87
	JUNE	6.47 ± 0.50	8.27 ± 0.31	6.17 ± 0.75	9.60 ± 2.5	8.87 ± 2.02	7.80 ± 1.31	8.90 ± 1.82	5.80 ± 2.00	12.50 ± 1.50	10.20 ± 0.72
	JULY	8.00 ± 0.26	5.87 ± 0.25	5.47 ± 0.50	8.33 ± 0.66	10.00 ± 0.87	7.63 ± 0.45	8.12 ± 0.10	5.20 ± 0.40	8.17 ± 0.59	10.90 ± 0.95
	AUG.	10.40 ± 1.44	7.37 ± 0.57	5.43 ± 1.27	12.23 ± 0.68	9.30 ± 0.30	10.53 ± 2.16	6.40 ± 1.22	6.87 ± 1.06	12.03 ± 2.82	10.23 ± 1.25
	SEP.	6.33 ± 0.31	7.17 ± 0.27	7.63 ± 0.64	10.10 ± 0.10	11.13 ± 1.10	6.67 ± 0.15	5.93 ± 0.61	5.43 ± 0.15	6.03 ± 0.93	9.33 ± 0.42
	OCT.	6.90 ± 0.10	7.63 ± 0.93	8.93 ± 0.61	9.70 ± 0.44	12.37 ± 1.55	4.43 ± 0.57	5.70 ± 0.61	5.53 ± 0.42	8.67 ± 0.64	11.03 ± 0.91
	NOV.	5.63 ± 0.64	7.97 ± 1.05	5.57 ± 0.84	10.40 ± 0.26	16.87 ± 3.33	5.67 ± 0.31	7.00 ± 1.08	4.13 ± 0.42	6.63 ± 0.57	10.80 ± 0.50
	DEC.	5.40 ± 0.75	4.67 ± 1.24	4.10 ± 0.26	7.67 ± 1.16	7.30 ± 2.11	4.6 ± 0.78	6.37 ± 0.55	4.57 ± 0.38	6.63 ± 0.55	5.93 ± 0.21
	JAN. 1982	3.83 ± 0.21	3.67 ± 0.31	2.97 ± 0.06	5.77 ± 0.48	4.67 ± 0.83	3.07 ± 0.15	3.07 ± 0.15	3.06 ± 0.29	3.33 ± 0.49	4.27 ± 1.10
	FEB.	4.80 ± 0.35	5.13 ± 0.61	5.10 ± 0.95	8.07 ± 0.83	6.93 ± 0.45	4.31 ± 0.55	3.43 ± 0.40	4.63 ± 0.35	6.00 ± 0.27	5.35 ± 2.03
	MAR.	5.80 ± 0.53	5.60 ± 4.53	5.40 ± 0.95	9.85 ± 0.84	8.70 ± 0.95	5.4 ± 0.53	5.50 ± 0.53	5.03 ± 0.32	9.40 ± 0.60	8.60 ± 0.89

TABLE - 17

PERCENTAGE OF FAT IN THE BODY COMPONENTS OF C. MADRASENSIS DURING APRIL 1981 - MARCH 1982; EACH VALUE REPRESENTS THE AVERAGE ESTIMATE OF 5 SAMPLES (MEAN ± S.D.)

SIZE GROUP (MM)	MONTH & YEAR	FEMALE					MALE				
		MANTLE	GILL	ADDUCTOR MUSCLE	HEPATOPAN-EREAS	GONAD	MANTLE	GILL	ADDUCTOR MUSCLE	HEPATOPAN-EREAS	GONAD
31-40	APRIL 1981	9.03 ± 1.00	5.97 ± 0.49	4.70 ± 0.26	5.37 ± 1.36	9.53 ± 0.81	5.17 ± 0.45	5.73 ± 0.64	4.37 ± 0.67	8.67 ± 0.49	10.27 ± 1.10
	MAY	8.47 ± 0.74	5.17 ± 0.25	4.90 ± 0.26	7.20 ± 1.57	13.40 ± 1.85	6.13 ± 0.67	8.8 ± 1.37	7.37 ± 0.9	9.97 ± 1.62	9.87 ± 1.94
	JUNE	6.00 ± 0.36	6.20 ± 0.61	6.43 ± 1.27	8.40 ± 0.87	8.40 ± 1.18	6.40 ± 0.72	8.27 ± 0.64	5.80 ± 0.42	10.47 ± 1.12	8.67 ± 0.64
	JULY	7.7 ± 0.36	11.07 ± 0.90	6.67 ± 1.30	10.01 ± 0.65	10.70 ± 1.18	7.20 ± 0.36	9.4 ± 2.39	6.17 ± 0.75	11.03 ± 0.91	9.90 ± 0.44
	AUG.	8.53 ± 1.10	9.40 ± 2.39	5.13 ± 0.96	12.90 ± 0.52	12.90 ± 0.17	10.43 ± 2.23	10.67 ± 3.77	7.03 ± 0.85	11.13 ± 2.57	13.07 ± 2.25
	SEP.	8.80 ± 1.11	6.73 ± 1.72	5.73 ± 1.10	9.17 ± 1.02	10.43 ± 0.32	6.17 ± 0.96	5.37 ± 6.21	5.03 ± 0.06	8.20 ± 0.20	10.40 ± 0.46
	OCT.	8.27 ± 1.46	5.13 ± 1.86	5.33 ± 0.25	9.93 ± 0.72	13.00 ± 0.85	6.57 ± 0.90	5.1 ± 1.51	5.97 ± 0.96	8.67 ± 0.21	10.27 ± 0.50
	NOV.	6.43 ± 0.49	7.17 ± 0.72	5.80 ± 1.06	7.87 ± 0.42	14.57 ± 0.38	5.67 ± 0.58	5.57 ± 0.91	5.03 ± 0.95	8.23 ± 0.67	10.17 ± 1.11
	DEC.	5.53 ± 0.50	6.23 ± 0.40	5.40 ± 0.40	6.63 ± 0.38	6.07 ± 1.05	4.33 ± 0.51	5.17 ± 0.15	4.43 ± 0.59	9.30 ± 0.61	6.60 ± 1.04
	JAN. 1982	3.93 ± 0.12	3.90 ± 0.26	3.30 ± 0.36	7.00 ± 0.95	4.23 ± 0.85	2.80 ± 0.20	3.27 ± 0.46	3.17 ± 0.21	3.73 ± 0.12	3.93 ± 0.12
	FEB.	5.23 ± 1.40	5.80 ± 1.04	4.57 ± 0.59	7.90 ± 1.70	6.50 ± 1.15	4.03 ± 0.25	3.77 ± 0.59	4.33 ± 0.58	6.17 ± 0.25	6.40 ± 0.52
	MAR.	5.07 ± 0.31	5.10 ± 0.17	4.97 ± 1.00	10.77 ± 0.21	9.20 ± 0.53	6.37 ± 1.52	4.93 ± 0.31	4.80 ± 1.06	9.43 ± 0.25	7.93 ± 0.42
41-60	APRIL 1981	9.60 ± 1.40	6.37 ± 0.93	4.77 ± 0.68	7.63 ± 2.08	12.67 ± 3.98	8.40 ± 0.6	7.90 ± 1.51	4.35 ± 1.50	6.72 ± 0.46	11.41 ± 0.96
	MAY	7.90 ± 0.36	5.46 ± 0.25	4.32 ± 1.65	8.90 ± 0.65	13.2 ± 1.25	7.80 ± 0.2	8.90 ± 0.37	6.89 ± 0.38	8.74 ± 0.65	10.03 ± 0.46
	JUNE	6.70 ± 1.54	5.47 ± 1.42	5.47 ± 0.50	10.57 ± 2.14	9.83 ± 1.88	7.63 ± 1.58	7.70 ± 1.18	6.83 ± 1.20	14.13 ± 3.01	9.43 ± 0.50
	JULY	8.50 ± 0.61	9.07 ± 0.86	6.50 ± 1.65	9.57 ± 0.65	9.33 ± 1.25	8.40 ± 0.61	9.03 ± 0.70	5.40 ± 0.90	12.43 ± 0.70	8.67 ± 0.21
	AUG.	9.73 ± 2.00	10.77 ± 3.68	8.00 ± 2.65	13.85 ± 1.94	10.77 ± 1.08	7.63 ± 0.55	8.37 ± 0.55	7.40 ± 0.53	11.63 ± 5.54	10.90 ± 1.01
	SEP.	7.53 ± 0.31	8.37 ± 1.18	7.53 ± 2.19	10.00 ± 0.69	9.47 ± 0.42	6.20 ± 0.20	7.53 ± 0.74	5.47 ± 0.38	9.83 ± 0.67	8.33 ± 0.32
	OCT.	7.67 ± 0.12	6.93 ± 0.92	5.67 ± 0.55	8.73 ± 0.55	14.00 ± 2.7	7.00 ± 0.92	7.23 ± 0.21	6.00 ± 0.82	9.20 ± 0.6	11.73 ± 0.47
	NOV.	7.37 ± 1.27	7.47 ± 1.56	5.87 ± 1.03	10.53 ± 1.33	13.57 ± 2.12	6.50 ± 0.53	5.90 ± 0.10	5.13 ± 0.31	8.67 ± 0.31	12.13 ± 0.50
	DEC.	5.33 ± 0.64	7.83 ± 0.38	5.48 ± 0.46	8.17 ± 0.87	5.93 ± 1.06	6.67 ± 0.59	6.10 ± 0.26	5.10 ± 0.44	9.87 ± 0.81	7.43 ± 0.57
	JAN. 1982	3.50 ± 0.36	3.33 ± 0.45	2.87 ± 0.25	8.27 ± 0.64	4.87 ± 1.36	3.07 ± 0.21	3.73 ± 0.64	3.10 ± 0.46	4.03 ± 0.15	3.97 ± 0.15
	FEB.	5.67 ± 1.67	6.53 ± 0.76	5.70 ± 1.32	7.30 ± 0.62	6.27 ± 1.33	4.63 ± 0.61	5.47 ± 0.55	4.10 ± 0.35	6.83 ± 0.71	6.1 ± 0.75
	MAR.	5.97 ± 1.25	5.53 ± 0.50	5.83 ± 1.27	11.53 ± 0.64	9.93 ± 0.12	4.80 ± 0.35	5.13 ± 0.76	4.87 ± 0.12	10.03 ± 0.67	9.93 ± 0.50

TABLE - 18

PERCENTAGE OF CARBOHYDRATE IN THE BODY COMPONENTS OF C. MADRASENSIS DURING APRIL 1981- MARCH 1982; EACH VALUE REPRESENTS THE AVERAGE ESTIMATE OF 5 SAMPLES (MEAN ± S.D.)

SIZE GROUP (MM)	MONTH & YEAR	BODY COMPONENTS									
		FEMALE					MALE				
		MANTLE	GILL	ADDUCTOR MUSCLE	HEPATOPAN-EREAS	GONAD	MANTLE	GILL	ADDUCTOR MUSCLE	HEPATOPAN-EREAS	GONAD
101-110	APRIL 1981	21.84 ± 2.31	17.78 ± 1.11	15.56 ± 4.00	16.67 ± 1.11	12.59 ± 2.31	21.38 ± 3.90	16.11 ± 0.56	12.96 ± 1.70	16.30 ± 0.64	16.30 ± 1.28
	MAY	20.74 ± 0.64	13.33 ± 0.56	6.31 ± 0.44	8.70 ± 0.64	10.97 ± 0.32	20.37 ± 0.85	11.11 ± 0.56	6.31 ± 0.44	7.96 ± 0.64	8.52 ± 0.32
	JUNE	22.08 ± 0.72	18.33 ± 1.91	14.58 ± 1.91	20.42 ± 0.72	18.47 ± 2.09	17.92 ± 1.44	21.67 ± 1.91	14.58 ± 1.91	19.17 ± 2.60	19.58 ± 0.72
	JULY	25.0 ± 0.00	21.67 ± 0.72	12.15 ± 1.70	27.54 ± 3.66	35.00 ± 5.00	21.25 ± 2.17	18.75 ± 2.50	15.42 ± 2.60	30.42 ± 1.91	32.48 ± 1.23
	AUG.	21.25 ± 1.25	22.08 ± 1.91	16.67 ± 1.44	27.92 ± 0.72	24.58 ± 1.44	26.67 ± 1.91	22.08 ± 3.15	17.25 ± 2.50	27.02 ± 1.91	30.21 ± 1.30
	SEP.	16.25 ± 1.25	18.75 ± 2.50	12.92 ± 0.72	21.67 ± 2.60	21.25 ± 1.25	16.68 ± 1.09	17.92 ± 0.72	13.33 ± 0.72	23.96 ± 0.36	21.42 ± 2.60
	OCT.	19.62 ± 1.29	19.81 ± 1.40	15.93 ± 0.64	17.22 ± 2.96	19.94 ± 1.76	18.7 ± 0.86	18.89 ± 1.11	17.00 ± 0.56	20.96 ± 1.40	19.94 ± 0.56
	NOV.	16.11 ± 1.67	15.74 ± 0.85	10.74 ± 0.64	15.93 ± 0.64	15.59 ± 0.64	17.22 ± 0.96	14.44 ± 1.12	12.41 ± 0.32	15.93 ± 0.64	15.37 ± 0.32
	DEC.	14.26 ± 0.32	15.42 ± 0.72	13.33 ± 0.72	15.21 ± 0.36	15.83 ± 0.72	15.48 ± 1.29	14.63 ± 0.85	13.96 ± 0.36	15.21 ± 0.36	17.92 ± 0.72
	JAN. 1982	17.92 ± 0.72	19.58 ± 1.44	15.63 ± 0.63	20.42 ± 0.72	21.46 ± 0.36	16.67 ± 0.36	20.21 ± 0.36	16.28 ± 0.02	20.00 ± 0.63	19.58 ± 0.72
	FEB.	15.83 ± 2.60	15.56 ± 1.12	13.70 ± 0.64	18.15 ± 0.64	18.33 ± 0.55	18.63 ± 0.32	17.41 ± 0.64	14.07 ± 0.32	16.85 ± 0.32	17.41 ± 0.64
	MAR.	15.93 ± 0.64	14.17 ± 0.72	12.87 ± 1.52	14.17 ± 1.09	15.42 ± 0.72	16.46 ± 0.36	17.92 ± 0.72	17.27 ± 0.40	16.46 ± 0.96	15.62 ± 0.63
81-100	APRIL 1982	17.41 ± 0.64	15.92 ± 1.69	12.96 ± 1.70	14.07 ± 0.64	13.17 ± 1.28	21.48 ± 3.57	15.93 ± 0.64	14.07 ± 1.70	19.63 ± 0.64	16.67 ± 1.92
	MAY	21.48 ± 0.32	15.55 ± 2.93	7.57 ± 1.31	9.86 ± 0.35	11.48 ± 0.32	20.77 ± 0.67	13.52 ± 0.32	7.57 ± 1.31	10.93 ± 0.32	11.67 ± 0.96
	JUNE	25.00 ± 3.30	20.83 ± 0.72	13.75 ± 1.25	33.33 ± 0.72	17.30 ± 1.44	23.33 ± 1.917	19.71 ± 0.94	13.33 ± 0.72	25.33 ± 0.72	17.25 ± 1.85
	JULY	22.92 ± 1.91	20.00 ± 2.50	14.26 ± 0.32	26.67 ± 0.72	27.00 ± 3.97	23.33 ± 3.15	20.92 ± 1.91	16.67 ± 1.44	29.21 ± 0.72	30.42 ± 0.72
	AUG.	24.58 ± 2.60	22.29 ± 0.36	18.33 ± 0.72	25.83 ± 3.15	28.33 ± 1.19	27.92 ± 2.60	23.08 ± 2.60	18.75 ± 2.17	27.92 ± 1.91	33.17 ± 2.89
	SEP.	16.75 ± 1.25	19.37 ± 1.66	14.38 ± 0.63	21.25 ± 2.50	20.63 ± 1.88	21.67 ± 2.60	21.87 ± 0.63	13.96 ± 0.36	19.79 ± 2.01	20.5 ± 1.25
	OCT.	22.22 ± 1.11	18.33 ± 0.56	17.96 ± 1.15	14.63 ± 1.16	16.48 ± 0.85	23.70 ± 2.31	17.59 ± 1.16	16.93 ± 0.64	18.74 ± 2.14	17.51 ± 0
	NOV.	16.00 ± 1.12	18.15 ± 0.64	10.74 ± 0.64	17.96 ± 0.85	18.15 ± 0.64	17.04 ± 1.67	15.93 ± 2.32	11.85 ± 0.64	15.00 ± 0.56	16.11 ± 0.56
	DEC.	16.8 ± 0.63	16.25 ± 1.25	12.92 ± 0.72	17.29 ± 1.30	15.67 ± 3.18	15.18 ± 1.29	15.74 ± 0.32	12.92 ± 0.72	16.67 ± 0.72	13.38 ± 0.72
	JAN. 1982	18.13 ± 0.13	19.38 ± 0.63	15.63 ± 1.09	21.26 ± 1.26	22.5 ± 0.63	18.33 ± 1.91	18.33 ± 0.95	15.21 ± 0.36	20.00 ± 1.25	20.38 ± 1.01
	FEB.	17.29 ± 0.96	16.48 ± 1.16	13.69 ± 0.96	18.89 ± 1.12	19.26 ± 0.64	17.04 ± 0.64	14.48 ± 0.32	13.52 ± 0.32	16.67 ± 1.11	18.15 ± 0.64
	MAR.	15.93 ± 0.64	14.79 ± 1.80	13.75 ± 0.63	15.63 ± 1.08	18.75 ± 1.25	16.25 ± 1.25	13.33 ± 1.25	13.33 ± 0.72	16.25 ± .31	14.92 ± 0.72

TABLE - 19

PERCENTAGE OF CARBOHYDRATE IN THE BODY COMPONENTS OF C. MADRASENSIS DURING APRIL 1981 - MARCH 1982:

EACH VALUE REPRESENTS THE AVERAGE ESTIMATE OF 5 SAMPLES (MEAN ± S.D.)

SIZE GROUP (MM)	MONTH & YEAR	BODY COMPONENTS									
		FEMALE					MALE				
		MANTLE	GILL	ADDUCTOR MUSCLE	HEPATOPAN-EREAS	GONAD	MANTLE	GILL	ADDUCTOR MUSCLE	HEPATOPAN-EREAS	GONAD
61-[illegible]	APRIL 1981	[illegible] ± [illegible]	16.3 ± 1.28	15.00 ± 0.96	17.41 ± 2.80	15.56 ± 1.93	18.89 ± 2.22	18.52 ± 0.64	14.81 ± 1.70	17.04 ± 0.64	18.89 ± 1.11
	MAY	21.11 ± 1.11	15.29 ± 0.65	6.85 ± 0.67	11.30 ± 0.85	11.67 ± 1.47	22.41 ± 1.78	13.52 ± 0.64	7.83 ± 0.87	11.67 ± 1.47	9.81 ± 0.86
	JUNE	20.21 ± 0.96	18.33 ± 1.91	13.96 ± 0.96	18.75 ± 1.25	17.50 ± 1.25	21.25 ± 2.50	23.75 ± 1.25	15.42 ± 0.72	19.58 ± 0.72	21.25 ± 1.25
	JULY	25.00 ± 1.25	22.92 ± 0.72	18.75 ± 1.25	31.67 ± 3.15	30.42 ± 1.91	19.17 ± 0.72	20.00 ± 1.25	14.56 ± 1.91	26.67 ± 5.91	29.83 ± 1.44
	AUG.	22.5 ± 1.25	22.5 ± 1.09	16.67 ± 2.6	25.83 ± 1.91	20.83 ± 0.95	22.08 ± 2.60	20.00 ± 3.31	16.25 ± 3.75	21.29 ± 1.25	25.63 ± 0.63
	SEP.	19.59 ± 1.30	19.79 ± 0.36	13.13 ± 0.63	20.63 ± 0.63	25.42 ± 3.15	20.83 ± 1.91	18.75 ± 2.50	15.42 ± 1.44	21.25 ± 1.25	23.54 ± 0.95
	OCT.	20.00 ± 1.12	18.89 ± 1.11	16.70 ± 1.70	18.15 ± 0.64	21.10 ± 2.90	20.74 ± 1.70	18.33 ± 0.56	18.00 ± 0.56	20.56 ± 0.56	21.46 ± 1.70
	NOV.	18.15 ± 0.64	16.30 ± 0.64	14.74 ± 0.51	18.89 ± 1.11	16.11 ± 0.56	20.18 ± 0.85	20.74 ± 0.64	16.30 ± 0.64	17.41 ± 0.64	14.82 ± 1.29
	DEC.	17.92 ± 1.91	15.83 ± 0.72	13.33 ± 0.72	16.67 ± 1.44	18.33 ± 0.72	17.92 ± 1.44	15.83 ± 0.72	13.30 ± 0.72	15.42 ± 0.36	19.18 ± 0.72
	JAN. 1982	18.53 ± 0.36	18.75 ± 1.25	16.67 ± 0.72	21.04 ± 0.96	21.67 ± 1.91	19.58 ± 0.72	18.33 ± 0.72	16.67 ± 0.72	22.08 ± 0.72	19.58 ± 1.91
	FEB.	16.67 ± 0.56	17.78 ± 1.11	15.37 ± 0.37	18.33 ± 0.56	17.96 ± 1.15	15.20 ± 1.25	16.48 ± 0.32	15.19 ± 0.65	19.63 ± 0.64	16.67 ± 1.11
	MAR.	18.13 ± 0.63	15.00 ± 1.25	12.92 ± 0.72	17.5 ± 1.25	15.5 ± 3.31	17.41 ± 6.64	16.25 ± 2.50	12.75 ± 0.90	16.04 ± 0.36	14.92 ± 0.72
41-60	APRIL 1981	16.11 ± 0.56	17.41 ± 0.64	18.14 ± 0.63	18.14 ± 0.63	18.33 ± 1.11	16.89 ± 1.78	17.04 ± 0.64	13.33 ± 0.72	16.25 ± 3.75	14.82 ± 1.29
	MAY	22.41 ± 1.78	16.67 ± 1.92	7.96 ± 0.56	11.67 ± 1.47	11.11 ± 0.56	18.89 ± 2.22	16.25 ± 1.92	7.83 ± 0.87	12.92 ± 0.72	9.81 ± 0.86
	JUNE	18.75 ± 1.25	19.58 ± 0.72	14.38 ± 0.63	17.92 ± 0.72	18.33 ± 0.72	20.63 ± 0.63	18.12 ± 0.63	14.58 ± 0.72	18.75 ± 1.25	20.10 ± 2.34
	JULY	24.50 ± 2.65	20.42 ± 0.72	16.67 ± 1.44	27.92 ± 3.21	30.02 ± 2.41	22.08 ± 2.6	19.17 ± 0.72	16.25 ± 3.75	25.26 ± 3.68	21.33 ± 0.64
	AUG.	18.96 ± 1.30	17.92 ± 0.72	14.17 ± 0.72	23.26 ± 3.68	29.58 ± 0.72	20.54 ± 2.6	23.33 ± 2.60	15.83 ± 1.91	23.33 ± 2.60	23.96 ± 1.56
	SEP.	18.96 ± 0.36	22.92 ± 0.72	16.04 ± 0.36	22.71 ± 0.95	26.67 ± 1.44	18.54 ± 0.96	23.75 ± 1.08	17.08 ± 0.72	22.08 ± 1.91	22.29 ± 0.96
	OCT.	19.63 ± 1.49	19.11 ± 1.09	16.11 ± 0.56	21.48 ± 1.95	19.44 ± 0.56	22.96 ± 1.70	22.41 ± 0.85	15.00 ± 0.56	20.00 ± 2.22	21.11 ± 2.00
	NOV.	22.04 ± 0.32	22.18 ± 1.06	17.78 ± 1.11	18.15 ± 1.70	18.45 ± 0.74	20.18 ± 1.95	18.89 ± 1.11	13.33 ± 1.11	19.63 ± 1.28	20.33 ± 1.11
	DEC.	18.22 ± 0.66	19.17 ± 0.72	15.61 ± 0.36	18.22 ± 0.66	19.58 ± 0.72	19.58 ± 0.72	16.67 ± 0.72	13.33 ± 0.72	15.42 ± 0.72	18.75 ± 0.56
	JAN. 1982	16.67 ± 0.72	19.17 ± 0.72	16.67 ± 1.91	22.08 ± 0.72	21.67 ± 2.01	21.68 ± 2.72	25.83 ± 1.44	18.54 ± 0.36	20.58 ± 1.01	19.58 ± 0.72
	FEB.	16.85 ± 0.31	18.15 ± 1.28	13.78 ± 0.41	19.63 ± 0.64	17.04 ± 0.64	18.15 ± 1.70	22.96 ± 1.28	16.48 ± 6.32	18.15 ± 0.64	16.29 ± 0.64
	MAR.	18.75 ± 1.25	19.58 ± 0.72	12.92 ± 0.72	7.92 ± 1.44	18.33 ± 0.56	26.67 ± 0.72	20.83 ± 0.36	16.67 ± 0.72	16.67 ± 0.08	18.75 ± 1.25

steadily increased for the second peak. The body components gonad and hepatopancreas showed the similar variations in the carbohydrate content in relation to reproductive cycle. The mantle has shown a very high value of glycogen from April to May again indicating the storage of glycogen in the connective tissue of the mantle. During the rapid proliferation of gametes, during the second peak, the supply of glycogen was used, and by the end of the second spawning the amount of glycogen was at a minimum level. The amount of glycogen in the gill was slightly less than in the other body components, shows similar fluctuations, but rather inconspicuous. The carbohydrate content was found to be high in the month of July and August but showed a slight decline in September. When the gonad is ripe, th glycogen falls to a low level in the gonad and hepatopancr whereas in the adductor muscle it decreases greatly during this period.

BIOCHEMICAL LEVELS IN RELATION TO GAMETOGENESIS

There are remarkable variations in the protein, fa and carbohydrate levels especially in the gonad, hepatopancreas and mantle during the different stages of maturation of the gonad. The process of gametogenesis involve the formation and gradual growth of the male and female gametes. During this period, there is a gradual mobili-

zation of nutrients in the form of glycogen and fat in the gonad , as a result of which the protein level ultimately increases in the rully ripe gonads.

PROTEIN : The changes occurring in the protein level of the different stages of the gonads are illustrated in fig. 19(Table 20 & 21). The general trend in fluctuations in both the males and females seem to be the same, but the extent of changes in all the above biochemical parameters seems to differ in the gonad and hepatopancreas. In I stage of the reproductive cycle, the protein content of all the body components was found to be very low. The protein levels noted during this period both in the hepatopancreas and in the gonad were 42.5% and 37.5% in females. In males it was 44.5% and 42.5 %respectively. During the II stage which indicates further growth of the reproductive elements, the hepatopancreas and gonad in females showed a gradual increase of protein from the I stage. In males, the gonad also showed gradual increase in protein and a slight decline of the protein peak in the hepatopancreas. Growth of the oocytes in the III stage was fast and this stage was characterised by the presence of a long peduncle in the oocytes of the females and in the secondary spermatocytes of the males. During this period there was an intensive and quick rise in the protein content of the hepatopancreas and gonad both in the males and in the females. The mantle and gill of the female oysters also showed steep

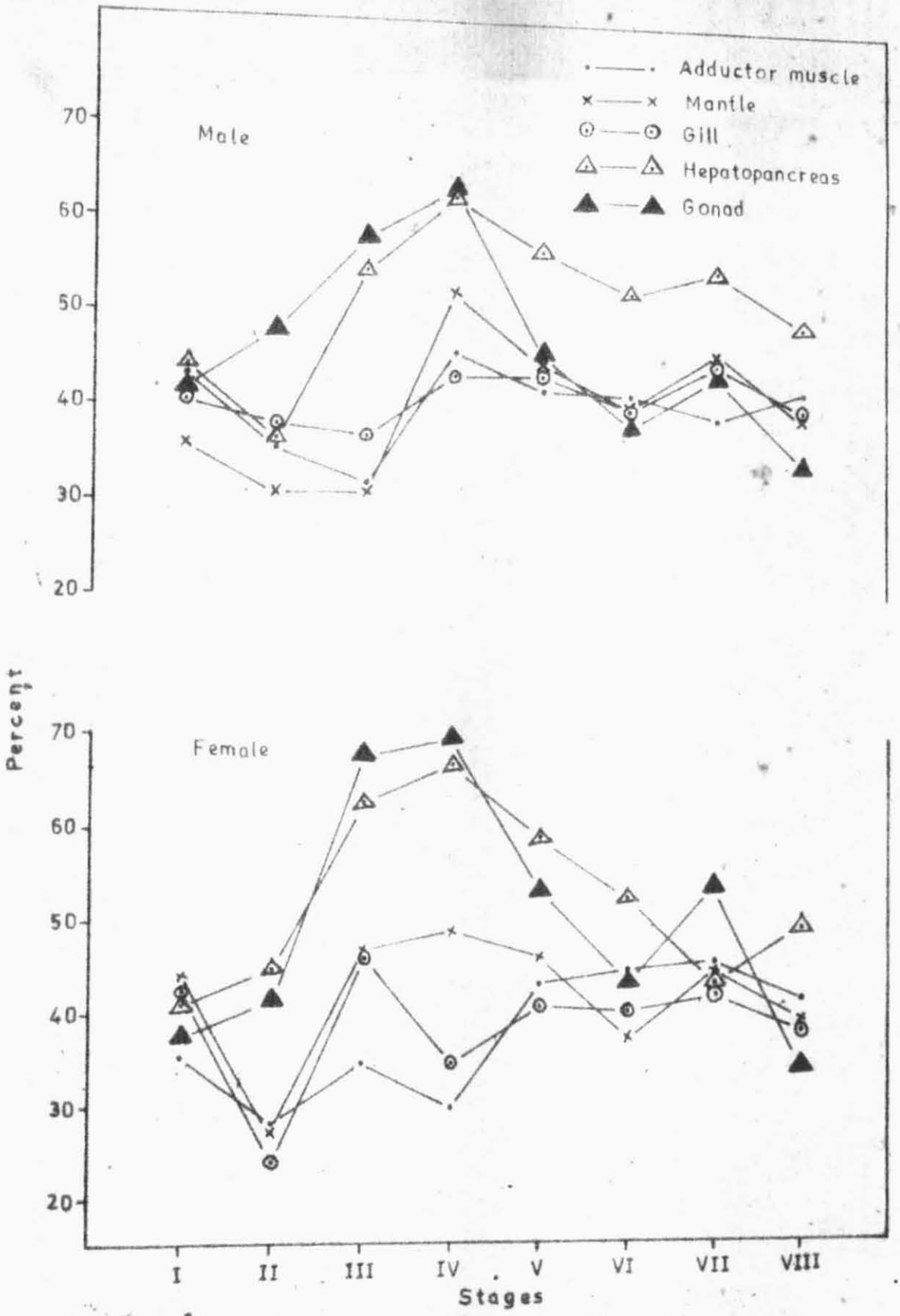


Fig.19 Protein level at the different stages of the oyster, C. madrasensis.

rise in the protein during this stage, but in male, it was found to decline very slowly. In the IV stage, the protein content of the hepatopancreas and gonad of the female oysters showed a very feeble increase. On the other hand, in the male oysters it was observed to increase steeply. The highest level of protein in the females was observed to be 67% and 69.5%in both the hepatopancreas and the gonad, and in the males, it was 62.4%and 63.4% respectively. The V stage of the gonad was characterised by the presence of a few ova in the females and partial shrinkage of the follicles in the males. As a result of the extrusion of of the reproductive elements, a sudden fall in protein concentration from IV to V stage was observed. The same trend of decrease in the protein concentration was noticed in the VI stage of the gonads in which the follicles were shrunken to a large extent and a large number of phagocytic cells made their appearance. During the V and VI stages, the hepatopancreas showed a higher level of protein than in the gonad. During the VII stage, the gonad showed the regressive condition during which autolysis and resorption of the reserved nutrients from the unspawned reproductive elements took place. The gonad alone of the female oyster showed a hike in protein level during this period, but in the male, both the hepatopancreas and the gonad showed the protein at an elevated level. In the indeterminate condition(VIII stage), the protein concentration of the

TABLE - 20

Quantitative changes (%) of Protein Fat and carbohydrate in the body components of female C. Madrasensis during different stages of Gonad, each value represents the average estimate of 5 to 6 samples (Mean ± S.D.)

Biochemical component	Body Components	Stages of Gonad															
		I		II		III		IV		V		VI		VII		VIII	
Protein	Mantle	44.5	1.00	27.5	3.41	47.0	2.00	49.5	1.67	46.4	1.67	37.6	5.40	45.3	6.53	39.2	4.15
	Gill	42.5	1.60	24.0	3.27	46.5	2.49	35.0	2.58	41.2	4.38	40.8	4.40	42.4	7.80	38.8	[illegible]
	Adductor muscle	35.5	4.12	28.5	4.12	35.0	3.80	30.0	2.31	43.6	2.97	45.2	8.20	45.6	6.69	42.0	4.00
	Hepatopancreas	42.5	1.91	45.0	4.76	63.0	2.00	6[illegible]	1.15	59.6	2.61	54.0	7.48	44.8	3.35	49.6	4.77
	Gonad	37.5	1.91	41.5	3.78	68.5	2.50	69.5	1.91	53.6	2.61	44.0	0.20	54.0	2.83	34.4	3.85
Fat	Mantle	8.5	0.61	10.4	1.44	9.0	0.12	7.4	1.47	5.3	0.95	4.2	0.38	3.83	0.21	6.5	0.50
	Gill	9.1	0.86	7.4	0.57	8.6	1.40	7.5	0.5	7.5	1.31	3.7	0.15	3.67	0.31	8.3	0.31
	Adductor muscle	6.5	1.65	5.4	1.27	5.5	0.15	6.3	1.44	5.4	0.79	3.4	0.20	2.47	0.06	6.2	0.75
	Hepatopancreas	11.6	0.65	12.2	0.68	6.5	0.36	9.1	1.22	6.4	0.47	5.2	0.36	5.77	0.49	9.6	2.50
	Gonad	9.3	1.25	9.8	0.30	12.0	0.65	14.9	1.40	9.4	1.18	3.7	0.21	4.67	0.83	8.9	2.02
Carbohydrate	Mantle	24.5	2.65	22.9	1.91	16.3	1.25	10.6	1.29	16.1	1.67	14.3	0.32	18.3	0.13	25.6	3.33
	Gill	20.4	0.72	20.3	2.50	18.8	2.50	19.8	1.40	15.7	0.85	15.4	0.72	19.4	0.63	20.8	0.72
	Adductor muscle	27.9	1.44	14.6	0.32	12.9	0.72	15.9	0.64	10.7	0.64	13.3	0.72	15.6	1.09	13.8	1.25
	Hepatopancreas	27.9	3.21	26.7	0.72	21.7	2.60	17.2	2.95	15.9	0.64	15.2	0.36	21.3	1.26	33.3	0.75
	Gonad	30.0	2.41	27.0	3.97	21.3	1.25	19.9	1.76	15.6	0.64	15.8	0.72	22.5	0.63	17.3	1.44

TABLE - 21

Quantitative charges (%) of Protein, fat and carbohydrate in the body components of male C. Madrasensis during the different stages of gonad, each value represents the average estimate of 5 to 6 samples (Mean ± SD)

Biochemical component	Body Components	Stages of Gonad I	II	III	IV	V	VI	VII	VIII
Protein	Mantle	36.6 ± 3.27	31.0 ± 2.00	31.0 ± 3.82	52.4 ± 3.29	45.2 ± 1.79	40.4 ± 2.97	16.4 ± 3.85	39.2 ± 4.15
	Gill	40.5 ± 3.42	38.5 ± 4.12	37.0 ± 3.83	43.6 ± 3.84	44.4 ± 4.98	40.4 ± 6.69	44.8 ± 3.9	38.8 ± 3.35
	Adductor Muscle	43.0 ± 3.83	36.0 ± 3.65	32.0 ± 0	46.6 ± 6.16	42.0 ± 2.00	41.6 ± 4.56	39.2 ± 3.35	42.0 ± 4.00
	Hepatopancreas	44.5 ± 2.52	36.0 ± 2.82	54.5 ± 5.00	62.4 ± 5.18	57.2 ± 1.79	53.2 ± 9.45	55.2 ± 8.67	49.6 ± [illegible]
	Gonad	42.5 ± 2.52	48.0 ± 4.32	58.0 ± 6.00	63.4 ± 3.78	45.6 ± 2.19	44.0 ± 9.38	38.8 ± 5.22	34.4 ± 3.85
Fat	Mantle	8.4 ± 0.61	10.5 ± 2.16	8.5 ± 1.19	6.8 ± 1.10	4.5 ± 1.23	3.4 ± 0.06	3.1 ± 0.15	6.5 ± 0.50
	Gill	9.0 ± 0.70	6.4 ± 1.22	7.2 ± 0.21	4.8 ± 0.56	5.0 ± 0.35	3.7 ± 0.31	3.1 ± 0.15	8.3 ± 0.31
	Adductor Muscle	5.4 ± 0.90	6.9 ± 1.06	6.8 ± 0.57	5.5 ± 0.64	4.2 ± 1.00	3.7 ± 0.61	3.1 ± 0.29	6.2 ± 0.75
	Hepatopancreas	10.6 ± 0.70	10.0 ± 2.82	9.2 ± 0.55	8.6 ± 0.55	5.2 ± 1.00	3.7 ± 0.15	3.3 ± 0.49	9.6 ± 2.50
	Gonad	8.7 ± 0.21	10.2 ± 1.25	11.3 ± 0.70	11.9 ± 0.76	5.4 ± 1.08	3.6 ± 0.35	4.3 ± 1.10	8.9 ± 2.02
Carbohydrate	Mantle	22.1 ± 2.60	27.9 ± 2.60	16.9 ± 1.09	11.9 ± 0.85	17.2 ± 0.96	15.2 ± 1.29	18.3 ± 1.91	25.0 ± 3.33
	Gill	19.2 ± 0.72	23.1 ± 2.60	17.9 ± 0.72	18.9 ± 1.17	14.4 ± 1.12	14.6 ± 0.85	18.3 ± 0.95	20.8 ± 0.72
	Adductor muscle	16.3 ± 3.75	18.8 ± 2.17	13.3 ± 0.72	15.0 ± 0.56	12.4 ± 0.32	14.0 ± 0.36	15.2 ± 0.36	13.8 ± 1.25
	Hepatopancreas	25.3 ± 3.68	27.9 ± 1.91	23.9 ± 0.36	21.0 ± 0.96	15.9 ± 0.64	15.2 ± 0.36	20.0 ± 1.25	33.3 ± 0.75
	Gonad	21.3 ± 0.84	23.2 ± 2.89	21.4 ± 2.60	19.9 ± 0.56	15.4 ± 0.32	17.9 ± 0.72	20.5[illegible] ± 1.01	17.3 ± 1.44

gonad of the male and female oysters fell to a low level compared to all the other body components, but in the hepatopancreas alone it was found at an elevated level.

FAT : The fat content was found to vary with the maturation of the gonads, body growth of the oysters and also with the intensity of feeding. The fat content variations during the different stages of the oocyte development changes in the different body components and its trend during the post-spawning period are illustrated in fig.20 (Table 20 & 21). During the I stage, the gonad showed lower level of fat than in the hepatopancreas both in the male and female oysters. During the II stage of the gonad there was a slight increase in the fat level in the gonad of both the male and female oysters, but in the hepatopancreas it showed a fall in the male but a very feeble increase in the female. During the III stage, there was a sudden fall in the fat level of the hepatopancreas, reflecting a steep rise in the gonad of the female oysters. In males, the level of fat showed the same trend as in the female oysters but the increase in the gonad and decline in the hepatopancreas was very feeble. There was a furthermore steady increase in the fat level during the IV stage of the female and a gradual increase in the male oysters. The hepatopancreas showed a slight hike in the fat of the female and this may be due to high intensity

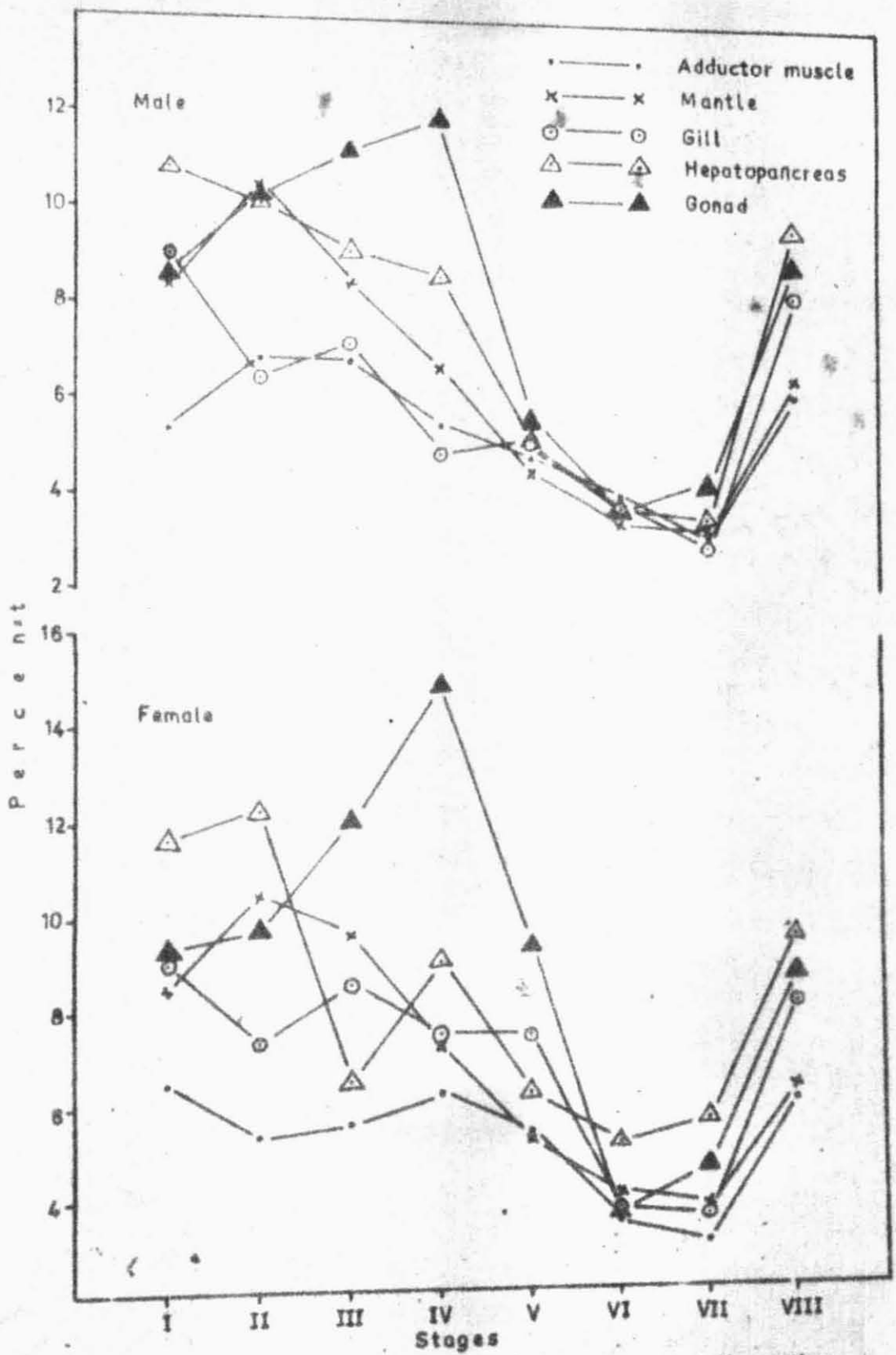


Fig. 20 Fat level at the different stages of the gonad of the oyster, C. madrasensis.

of feeding during this period. In the male oysters the hepatopancreas showed a decreasing trend. The maximum level of fat observed was 14.93% and 11.93% in the gonad of both the female and the male oysters respectively. IN the V stage there was a sudden fall in the level of the fat in gonad and hepatopancreas of both the male and female oysters indicating the extrusión of a large number of reproductive elements from the gonad. In the fully spent condition (VI stage), again there was a steep decline in the gonad of the female oyster and in the male a slow fall was observed. In the regressive condition(VII stage), actually reabsorption of fat from the gametes takes place. The increase of fat in the hepatopancreas may be due to the high intensity of feeding. This was clear by the presence of higher quantity of fat in the hepatopancreas than in the gonad of the female oysters. During the indifferent condition of the gonad (VIII stage), all the body components showed an increasing trend of fat content.

CARBOHYDRATE : The changes occurring in the quantity of carbohydrates in the different body components are illustrated in fig. 21. As a rule, the glycogen remains at a high level until the rapid proliferation of of sex cells, and declines gradually thereafter. During the I stage, the carbohydrate was found to be high in all the body components. The hepatopancreas and gonad showed

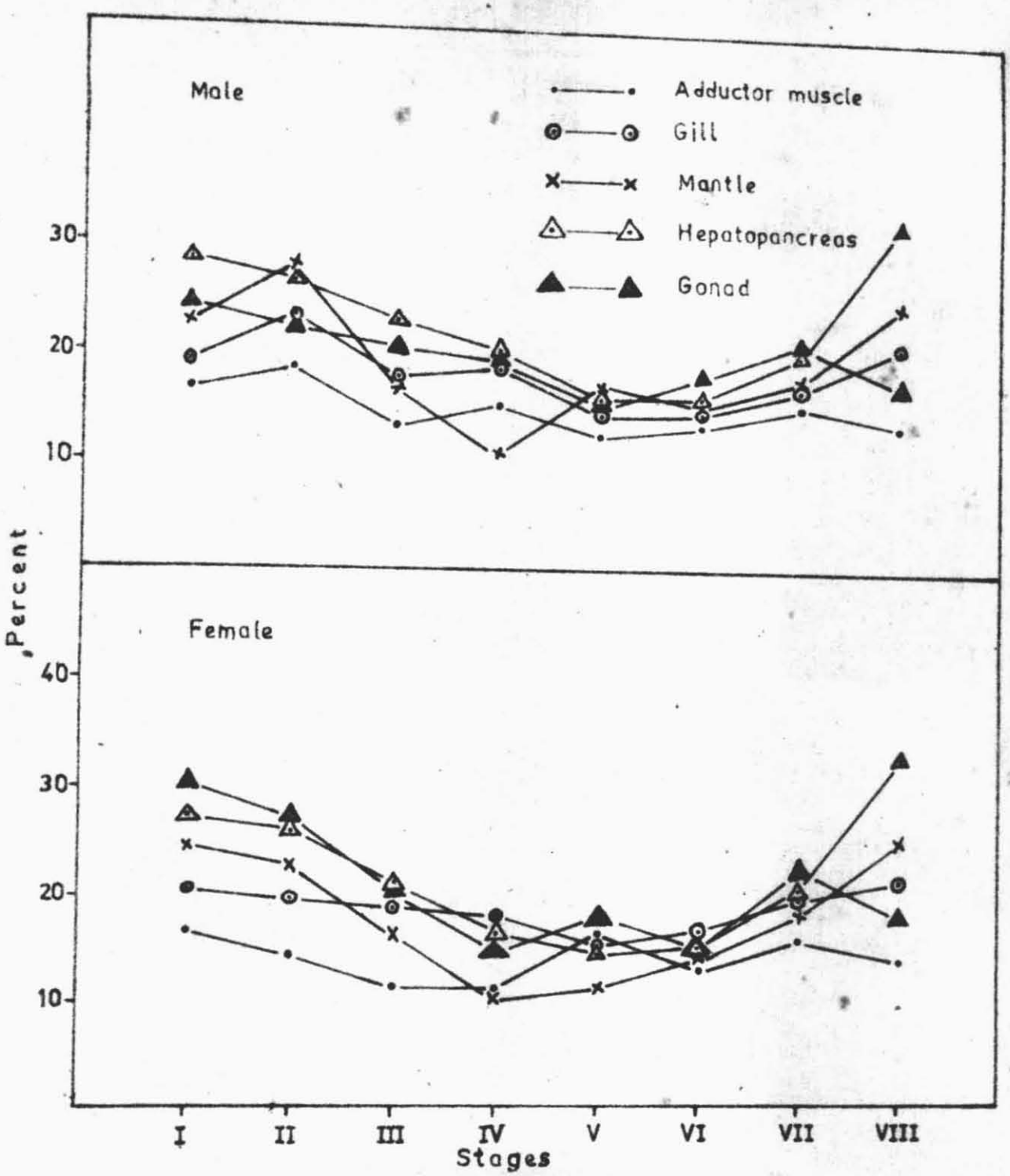


Fig. 21 Carbohydrate level at the different stages of the gonad of the oyster, C. madrasensis.

the highest levels of carbohydrate, followed by the mantle, gill and the adductor muscle. The carbohydrate level has been found to decline gradually from the I stage to the IV stage, when the gonad reached the fully ripe condition. In the V stage, there were no significant changes in the carbohydrate level because of the elimination of gametes from the gonad. Finally, there were no changes at all in the carbohydrate level in all the body components during the VI stage. Even if there were changes in hepatopancreas and gonad, there were very insignificant. During the period of autolysis and regression (VII stage), there was a slight increase in the carbohydrate level in all the body components, but the gonad and hepatopancreas showed more significant rise. In the indeterminate condition of the gonad, hepatopancreas showed the highest level of carbohydrate indicating that it is the primary storage organ, and during the same period of indifferent stage, the hepatopancreas also showed the maximum of carbohydrate content. Mantle showed the second place in the order of abundance of carbohydrate, indicating that it is the secondary storage organ for glycogen. During the storage period the mantle seems to increase in its thickness.

BIOCHEMICAL LEVELS IN RELATION TO FEEDING

The conservation of energy as reserves and the utilization of reserves in relation to gamete development are chiefly dependent upon the food intake of the animal. High intensity of feeding results in the storage of glycogen and fat contents and in the maturation of the gonads in the oysters.

Oysters were observed to feed actively at the beginning of gametogenesis, but feed poorly during their ripe condition. They also show poor feeding during the monsoon, perhaps due to the prevalence of low saline conditions in the lake. During the post-spawning, oysters feed very actively to meet the energy lost during spawning. Such changes in feeding have a profound influence on the biochemical levels of the oysters.

Two peaks of feeding intensity were observed, the primary one during May-June and the secondary one during December to May.

Though the peak intensity of feeding was during May-June, yet the concentrations of proteins in all the body components of the oysters showed a declining trend as a result of active spawning during May. The fat level in the hepatopancreas has shown an increasing trend during May-June coinciding with the high intensity of feeding

and decreasing trend in the gonad due to the spawning of oysters. The carbohydrate level has steadily increased in all the body components from May to July, coinciding with the primary peak of feeding intensity. During the secondary peak of feeding intensity in January the protein level of all body components showed a decreasing trend in both the sexes, with the exception of the gonad and hepatopancreas of the females. The lipid content showed a declining trend in all the body components, but the hepatopancreas showed a high level. As a result of heavy feeding, there was again increase in the glycogen in the gonad and hepatopancreas.

The low intensity of feeding during the active gametogenesis in October resulted in the drastic reduction of protein in the gonads and hepatopancreas of males and females. The low feeding intensity resulted in the reduction of lipid level in the hepatopancreas and rise in the carbohydrate level in the adductor muscle and in mantle. The protein level was very low in all the body components except in the hepatopancreas during August when the feeding intensity was very low. During the month of February, the protein level of all the body components was observed to be at a very low level but at a constant level. The lipid level has showed an increasing trend and the carbohydrate was found to decrease gradually during this period.

On summing up all the above observations, the peak intensity of feeding resulted in the accumulation of glycogen in the gonad and the lipid in the hepatopancreas to be used subsequently in the process of gametogenesis. At the time of gametogenesis, the feeding intensity was at a moderate level and hence the reserve food in the form of glycogen in the gonad and fat in the hepatopancreas were fully utilised for the maturation of the gametes. During this period, as it was mentioned by Sastry (1979) protein concentration rises at the expense of the carbohydrate.

BIOCHEMICAL COMPOSITION IN RELATION TO SALINITY

The biochemical composition of the oyster changes in relation to environment. Among the environmental parameters, salinity and temperature play important roles in the biochemical composition of the oysters. Fluctuations in the moisture content due to absorption of water, and loss of solids from the body of the animals are the most significant factors that bring about changes in the biochemical and chemical composition of the oyster meat. It was found in some bivalves that the seasonal fluctuations in the biochemical constituents were reciprocal with the seasonal variations in the water content(Venkataraman and Chari, 1951; Fuji, 1957; Joshi and Bal, 1965; and

Deshmuck, 1972). However, Nagabhushanam and Mane (1975) found no such inverse relationship.

Whenever the salinity was high, the protein and the fat levels of the oysters were also found to be high, coinciding however with the gametogenesis in the gonad of the oyster. During the monsoon, the salinity dropped off to the lowest level which triggered the oysters to spawn, and as a result the protein and fat levels also fell suddenly. The carbohydrate level was at its maximum during July, and the salinity was also correspondingly high, but the carbohydrate gradually went down till the maturation of the gonads during this period. Soon after spawning, due to the low saline conditions, water was absorbed into the body and some salts were lost and also due to the depletion of carbohydrate in the mantle, the water content was found to be high. Thus the above organic constituents and the high salinity of the water showed no inverse relationship. But under the saline conditions, the oyster may lose salts and gain water so that the water percentage rises in C. madrasensis, indicating a reciprocal relationship of water content with protein. The low salinity showed indirect effect on the biochemical constituents of the animal by lowering the available food, rather than by the direct inhibition of sexual maturation.

BIOCHEMICAL CONSTITUENTS IN DIFFERENT SIZE-GROUPS OF OYSTERS

The protein content of all the body components of the different size-groups of oysters is given in Tables 14 & 15. The range of protein level will vary from tissue to tissue, and the same is applicable for all the size-groups (41-60 mm, 61-80 mm, 81-100 mm and 101-120 mm) the maximum protein content was observed in the 41-60 mm size-group of oysters.

The lipid level was found to be varying between 4.17 % and 9.37 % and between 3.37 % and 10.07 % in the mantle of both males and females of the 101-120 mm size-group of oysters. The lipid content of the gill showed fluctuations between 3.73 % and 8.6 %; and between 3.53% to 8.23% for both the females and males respectively. The adductor muscle had a very low value of lipid content when compared to all the other body components. The fat level was found between 3.4 % and 6.57 % and between 3.17 % to 7.85 % for both the females and males. Among all the body components, the hepatopancreas and gonad showed the highest lipid content though with lot of fluctuations. The prominant peaks in the lipid level was observed in the females, but not in the males, in all the size-groups. In the 41-60 mm size-groups of oysters, the fluctuations have not shown a definite trend.

Higher level of carbohydrate was found in the 101-120 mm size-group of female oysters during July. This level was found to increase gradually up to 27.92% in the 41-60 mm size-group of female oysters. Gonad showed the highest level of carbohydrate during July and showed the lowest level during May in the 101-120 mm of size of oysters It was found to go down to 30.02% in the small or 41-60 mm size-group of oysters. The same trend of reduction in carbohydrate level was observed in the male oysters also.

DISCUSSION

Considerable work has been carried out on the biochemical composition of the different body components of various pelecypods (Galtsoff, 1964; Giese,1966 & 1969; Giese et al.,1967; Nagabhushanam and Lomte, 1972; Nagabhushanam and Mantale, 1972; Nagabhushanam and Mane, 1973, 1974; Gabbott, 1975, 1976; Mane and Nagabhushanam, 1975; Lawrence, 1976; Bayne, 1976a and Stephen 1980). Earlier workers (Milroy, 1907; Mitshell, 1916; Russel, 1923; Okazaki and Kobayashi, 1929; Sekine et al.,1929; Masumoto et al., 1934; Tully, 1936; Hatanaka, 1940; Baker et al., 1942; Venkataraman and Chari, 1951; Usuki and Koizumi, 1954; Tobias and Silva, 1955; Lee and Pepper, 1956; Silva et al., 1956; Wentworth and Lewis, 1958; Fieger et al., 1958; Durve and Bal, 1961; Antunes and Ito, 1968; Gromosova,1968; Walne, 1973; Bonilla Reiz, 1975; Hollan and Hansat, 1976;

Krishnamurthy et al., 1979; and Riley, 1980) attempted the biochemical estimations on oysters by homogenising the entire animal and correlating them with the reproductive cycle, feeding and other metabolic activities. Giese (1967) emphasized the importance of the study of the biochemical variations in the different body components to find out the migration of nutrients if any, among them.

The biochemical composition varies for different species of oysters, and even for the same species, under different conditions (Pease, 1932). Seasonal variations in the biochemical levels of Ostrea edulis have been reported by Russel (1923) and Couteaux-Bargeton (1947).

In the present study, protein level in all the body components showed fluctuations during this period. However, gonad and hepatopancreas showed higher level of protein than the other body components, agreeing with the views of Giese et al.,(1967); Giese (1969); Deshmuck(1972); Nagabhushanam and Mane (1974). As in all other bivalves, there is a change in the protein level during the maturation and spawning of the oysters. The protein level was observed to be at its peak during the maturation and it declined during the spent condition, during the monsoon season. A similar trend has been observed in all the body components but their fluctuation seems to be very

feeble. These observations agree with those of Masumoto et al.,(1932) in the British oysters and of Tully (1936) in Ostrea lurida, O. virginica and O. gigas. The low level of protein was observed to continue for about one and half months and this may be due to the low saline conditions affecting the availability of food in the water. During the monsoon period, when the salinity is very low, the oyster may lose salt and gain water so that the percentage of water rises and as a result there is a reciprocal relationship of the water content with the protein, fat and glycogen contents. This agrees with the views of Daniel(1922) and Fraga (1956a,b,c) in Mytilus edulis; Hori (1954) in Corbicula sandii; Venkataraman and Chari (1951) in Ostrea madrasensis; Fuji (1957) in Corbicula japanicum; Durve and Bal (1961) in Crassostrea gryphoides and Nagabhushanam and Talikhedkar (1977) in Donax cuneatus.

During the period of gametogenesis, the protein level was observed to rise slowly from the I stage to the II stage; and also from the III stage to IV stage. Steep rise in the protein of the gonad and of the hepatopancreas was observed during the II to the III stage. This is suggested to be due to the fast growth of oocytes during this period. Fall in the protein level from the V to the VI stage and during the regressive condition of gonad was also observed.

Nagabhushanam and Bidakar (1975) observed that instead of the protein decreasing during the spawning season, it increases to a maximum level of 70% during December and remained at a high level for the rest of the period in C. cucullata, giving an average value of 56.73% Similar results were obtained by Quayle (1969) on the Pacific oyster, O. gigas, but the reason for the same was not given by him. Nagabhushanam and Bidakar (loc.cit.) have given the reason for this hike, saying that the oysters during the monsoon, as the salinity over the bed remains at a low level, are unable to carry on their normal activities so that all their metabolic activities got maintained at a basal level, and hence the protein level increases. I has been further observed that during the monsoon period the gonadal condition also was stationary.

Masumoto and Hibino (1939) and Masumoto et al.,(1934) observed that the female oysters contain lipid, twice as much as the males during gametogenesis. This view is applicable to the oyster, C. madrasensis also, but only about one and half times increase was observed in females. There were great differences in the lipid content of the pre-gravid and gravid oysters. In the pre-gravid oysters higher amount of fat was always found in the hepatopancreas but in the gravid ones it was found in the gonads. Fat

forms the reserve nutrient in the digestive gland. Mantle also showed a similar trend of fluctuation as in the hepatopancreas and acts as an intermediate storage organ accumulating fat during intense feeding and supplying the fat to the gonad at the time of gamete formation. Reciprocal relationship between the fat of the hepatopancreas and of gonad was also observed.

During the different stages of the maturation of the gonad the lipid level showed some interesting observations. The progress in the fat level was observed to be very slow from the I stage to II stage, but faster from the II to the IV stage of maturation. A sudden drop in fat was observed during the spawning as a result of extrusion of gametes, and this agrees with the views of Nagabhushanam and Dhamne (1977) in P. laterisulca; Masumoto et al.,(1934) in C. gigas ; Joshi and Bal (1956) in K. mormorata and Venkataraman and Chari(1951) in C. madrasensis. However, at the regressive and indifferent stages, there was a gradual increase in the fat content.

Venkataraman and Chari (1951) observed that the fat level in C. madrasensis was low in July and high in October-November; the low level in July was correlated with the growth, and the maturation of the gonad, and high level during October-November was due to the intensive

feeding and storage of fat, prior to spawning. In the present study, low level of fat in the gonad was observed during June and high level in October-November, whereas the hepatopancreas showed a slight rise in the fat content during June and a fall in October-November. The low level of fat in the gonad during June may be attributed to the growth of the oysters, but not due to the maturation of the gonad as is mentioned by the above workers. The high fat level in the gonad during October-November is mainly due to the transfer of the fat from the hepatopancreas and mantle in which it was stored during the high intensity of feeding. Tanaka and Hatano (1952) reported a rise in fat level owing to the growth of the body during the maturation of the pearl oyster, Pinctada martensii. In P. laterisulca the rise in fat level during December and January was mainly due to the formation of gametes in the rematured individuals prior to the second peak of spawning.

Carbohydrate of bivalves comprised mainly glycogen (Gabbott and Bayne, 1973) and the changes in the carbohydrate may be due to accumulation and utilization of glycogen at different stages like gametogenesis and spawning. The largest deposits were in the gonad during the indifferent condition when it is primarily composed of connective tissue. The carbohydrate content which was found to be high in the body components during the indifferent stage

was found to decline gradually from I to IV stages of the gonad. This agrees with the earlier investigations (Okazaki and Kobayashi, 1929; Masumoto et al., 1934; Tanaka and Hatano, 1952; Gabbott, 1964). The VIII stage is the regressive condition of gonad and as a result of the formation of connective tissue, the glycogen level also was found to be at a high level. Mantle appears to store glycogen during the month of July, as a result of which it seems to be a thick layer and is gradually reduced to a thin membrane at the time of spawning. Large stores of carbohydrate in the gonads of Teredo stultorum as well as in two other species, for eg., Teredo pedicellatus and Mytilus edulis indicate that the stored reserves may be utilised for gametogenesis (Giese et al., 1967; Gabbott, 1975). In C. gryphoides the glycogen decreased during the spawning period and during the commencement of recovery (Durve and Bal, 1961 and Nagabhushanam and Mantale, 1972).

Great variations were found to occur in the biochemical constituents of the gonad for the pre-gravid, gravid and spent oysters. Pre-gravid oysters were found to contain large amount of glycogen and less protein and lipids, whereas the gravid ones contain large amount of lipids and proteins and less glycogen, and the spent ones were found to lose considerable amount of lipids,

proteins and glycogen. This agrees with the views of Okazaki and Kobayashi, 1929; Humphrey, 1941; Nagabhushanam and Mane, 1975; Nagabhushanam and Bidakar, 1978; and Ansari *et al.*, 1975) have reported that generally in bivalves, the carbohydrate reserves may be rapidly utilised under unfavourable conditions and the great variations found in the tissues indicate that the level of mobilisable carbohydrate reserves may fluctuate widely and rapidly in response to the fluctuations in the maturation of the animal.

The present studies on the oyster, *C madrasensis* agree with the views of Giese (1966) implying the accumulation of glycogen and a considerable amount of lipids in the hepatopancreas to meet the requirement of the biochemical budget at the time of the production of gametes in the ovary. The loss of carbohydrates during the maturation of gametes suggests a massive conversion of carbohydrate into the gamete tissue.

A slight elevation in the carbohydrate level during the regressive condition of the gonad may be attributed to the formation of connective tissue around the unspawned gametes which accumulated carbohydrate from the nutritional sources.

In C. madrasensis when the gonad is in the process of ripening during September and October, the carbohydrate content falls to a low level in the gonad as well as in the hepatopancreas, whereas in the adductor muscle it increases greatly during this period. Similar results have been obtained by Ashikaga (1948) and Giese (1969) in Tivela stultorum.

The seasonal variations in the biochemical composition of the oysters vary with the geographic location. According to Okazaki and Kobayashi (1929) the glycogen content increased to a maximum in the Spring and the level continued to be quite high throughout July. During the breeding season in August and September, there was a sharp decline in glycogen to a distinct minimum. Biery et al. (1937) confirmed this observation using Ostrea edulis and C. angulata. Couteaux-Bargeton (1947) studied the glycogen content of gonads, digestive complex and the labial palps in C. angulata and found the greatest loss during the breeding season but observed a rapid recovery also.

Masumoto et al. (1934) studied the glycogen, fat and total nitrogen content in C. gigas and correlated them with the reproductive cycle. Glycogen content was found to be built up during the autumn and winter and this was called the period of 'fattening', which actually means accumulation of glycogen. He observed the peak value

of glycogen during the mid-season of gonad ripening and the peak of fat formation at the time of the most active formation of gametes. Similar observations were made for the same species by Usuki and Koizumi (1954). The present study of glycogen in the oysters does not agree with the views of Masumoto et al. (1934), which show its peak value just before the onset of gametogenesis. During the reproductive season, drop in glycogen value was observed by Hatanaka (1940) in Ostrea gigas, whereas protein and fat decreased in Summer. Humphrey (1941) observed that glycogen value dropped during the spawning period and hence the wet weight of the oyster, Gryphaea commercialis also dropped. Bargeton (1940) showed high concentration of glycogen in the mantle and in the labial palps in winter. Further Bargeton (1944) in the same oyster showed high fat content during gametogenesis.

The inter-relationship between food, site of each reserve and the utilisation of the reserves in relation to gamete development in Mytilus edulis have been discussed in detail by Gabbott and Bayne (1973) and by Bayne (1975, 1976). A detailed discussion of energy metabolism in Mytilus edulis the inter-relationship between the different body tissues, transformations of reserves have been given by Gabbott (1975,1976). In the oyster C. madrasensis it is clear that the energy is stored in the form of glycogen

in the gonad and hepatopancreas and in the form of fat in the hepatopancreas during the primary peak of feeding and this energy is utilised in the formation of gametes. The carbohydrate and fat levels also were found to be high in the mantle as a result of heavy feeding.

The low intensity of feeding during active gametogenesis resulted in the drastic reduction of protein in the gonad and hepatopancreas of the males, and in the process of maturation of gametes in the females.

CHAPTER FIVE

RNA, DNA AND INORGANIC PHOSPHATE CONTENT IN OYSTERS

In recent years, much attention has been paid to the study of the nucleic acids, because of their general usefulness, as for instance in the prediction of the growth rate of fishes or the measurement of biomass production of marine phytoplankton and zooplankton (Sutcliffe, 1965; Holm-Hansen et al., 1968). Biochemical techniques such as the measurement of cellular DNA content (Mirsky and Ris, 1951; Ohno et al.,1968; Hinegardner, 1968) and studies of protein similarities (Markert and Faulhaber, 1955; Wolf et al., 1969) come to play an important role in the assessment of evolutionary relationship among organisms. It has also been reported by Hinegardner (1968) that highly specialised fishes tend to have less DNA content per cell than the more generalised, or less evolved fishes of the same phylogenetic grouping. Brachet (1955) and Leslie (1955 have reported that the DNA content o

fish tissues will vary little, but the RNA content will vary much more and it will be highest in those fish undergoing fastest growth or protein synthesis. According to Bulow (1970) RNA concentration increases with higher feeding and faster growth rate. The higher level of RNA in the dark muscle when compared to the white muscle of the freshwater carp Barbus stigma is attributed to the greater metabolic activity in the black muscle (Jafri and Mustafa, 1976). There is circumstantial evidence for the fact that the RNA content is associated with the active metabolic processes, but concrete evidence of the direct participation of RNA in protein synthesis is very much recent. The synthesis of RNA in the several stages of maturation of some invertebrates has been carried out by Rythman (1964); Davidson et al. (1964); Das et al., (1965a); Gross et al., (1965); Dhainaut (1965); Sutcliffe (1965); Tweedell (1966); Allen (1967); Das (1968); Gould and Schnoeder (1969); Gould (1969a,b); Pollack and Telfer (1969); Bertout and Dhainaut (1971); Millar(1973); Davis and Wilt (1972); Miller and Epel (1973); Duspiva et al. (1973); Hinegardner (1971); Rice (1974); Davenport (1976); Zolakar (1976), Mermod et al. (1979); Mercy Bai (1980) and Kirchchoff(1981).

Hinegardner (1974) studied the cellular DNA of 110 species of molluscs and correlated it with the body size and confirmed that the generalised molluscs have a

higher amount of DNA than the specialised species. Oysters are highly specialised for the sedentary life they lead, with the total loss of foot, so that they are considered as specialised species, and hence with low amounts of DNA. Except for the report on the DNA content of oysters by Hinegardner (1974), no other literature is available on the nucleic acids of oysters. The present study was undertaken to find (1) the relationship between the RNA and DNA content of oysters, (2) the concentration of RNA, DNA and phosphate content in relation to sex, (3) to study their seasonal variations, (4) the quantitative changes of RNA, DNA and phosphate contents in different body components, (5) changes occurring in the concentration of RNA, DNA and inorganic phosphate content at various stages of maturation, (6) relation between the feeding intensity and the RNA, DNA and phosphate concentrations, and (7) to correlate the oyster meat weight with the DNA and RNA concentrations.

MATERIAL AND METHODS

The oyster samples collected from the natural beds in the Pulicat Lake were weighed individually. Oysters above 101-120 mm were utilised for the estimation of RNA, DNA and phosphate. After shucking, the sex and the maturation stage of each individual were noted. The body components such as mantle, gill, adductor, hepatopancreas and

gonad were also dissected out and weighed individually. Porcelain dishes along with the tissues were kept in an oven to dry them at 80°C till a constant weight was obtained. The dried tissue was ground into a fine powder and this powder was used for the estimation of RNA, DNA and the phosphate content.

100 mg of the tissue powder was taken and homogenised thoroughly with 5 ml of distilled water. 5 ml of 10 percent trichloroacetic acid was added. The precipitate was kept in ice for 30 minutes. After removing from the ice the precipitate was centrifuged well for about 10 minutes and was washed thrice with 10 trichloroacetic acid. After this, 5 ml of 5 percent trichloroacetic acid was added to it and kept in a boiling water bath for about 15 minutes so as to dissolve the precipitate. The tubes were centrifuged well and the supernatant was taken for analysis. The data used in this context is a mean of eight samples.

ESTIMATION OF RNA

RNA was estimated by the Orcinol method described by Schneider (1957). This method measures the ribose content of ribonucleic acid which is a measure of the RNA content.

REAGENTS : 1) Orcinol reagent was prepared by dissolving 1 gm of Orcinol in 100 ml of 12 N hydrochloric acid containing 0.5 gm of ferric chloride.

2) Standard RNA : This was prepared by dissolving yeast RNA in hot 5% trichloroacetic acid to give a concentration of 200 µg/ml.

PROCEDURE

1 ml of the trichloroacetic acid extract of the nucleic acids was made upto 2 ml with 5% trichloroacetic acid. A reagent blank as also a set of standards containing RNA was prepared. To a tube, 3 ml of Orcinol reagent was added. The contents were mixed and kept in a boiling water bath for 20 minutes. The tubes were taken out, cooled and the colour intensity was measured at 640 nm in a spectrophotometer. The values were expressed as mgm of RNA/100 mgm of dry tissue weight.

ESTIMATION OF DNA

The procedure by Burton (1956) was followed for the estimation of the DNA using diphenylamine reaction.

REAGENTS : 1) Diphenylamine reagent : 1.5 gm of recrystallised diphenylamine was dissolved in 100 ml of redistilled acetic acid and to this was added 1.5 ml of concentrated sulphuric acid. The reagent was stored in the dark at $4^{o}C$.

On the day of its use, 0.1 ml of aquous acetaldehyde (16 mg/ml) was added to every 20 ml of the reagent required.

2) Redistilled acetaldehyde in water (16mg/ml) was prepared and stored at $0^{o}C$.

3) Standard RNA solution : Highly polymerised calf thymus DNA (KCOH-light) solution was prepared in 5 mM sodium hydrochloride to give a concentration of 0.4 mg/ml. The working standard was prepared with an equal volume of 1 N perchloric acid and heating at $70^{o}C$ for 15 minutes.

PROCEDURE :

2 ml of the nucleic acid extract was mixed with 2 ml of diphenylamine reagent containing acetaldehyde. Tubes containing known amount of standard DNA and a blank containing 0.5 N perchloric acid but no DNA were also prepared. The colour was developed by incubating it at $30^{o}C$ for 16 hours. The colour intensity was measured in a spectrophotometer using a red filter at 640 nm. The values were expressed as mgm of DNA/100 mgm of dry tissue.

ESTIMATION OF INORGANIC PHOSPHATE

Inorganic phosphate content in different body components of oysters was estimated by the method of

Fiske and Subba Raw (1925). The proteins of the tissue were precipitated with trichloroacetic acid. The protein free filtrate is treated with an acid molybdate solution, which forms phosphomolybdic acid from any phosphate present. The phosphomolybdic acid is reduced by the addition of 1, 2, 4-aminonaphtholsulphonic acid reagent, to produce a blue colour whose intensity is proportional to the amount of phosphate present.

REAGENTS

10 percent Trichloroacetic acid : Dissolved 10 gm of reagent grade trichloroacetic acid in water and diluted to 100 ml.

10 N Sulphuric acid : Carefully added 450 ml of concentrated sulphuric acid to 1300 ml of water. To check, diluted 10 ml of this solution to 100 ml in a volumetric flask, mixed and titrated against 10 ml portion with with standard 1 N sodium hydroxide. From the titration results, the original solution was adjusted if necessary to make it exactly 10 N.

Molybdate solution : Dissolved 25 gm of reagent grade ammonium molybdate in about 200 ml of water. In a one litre volumetric — flask 300 ml of 10 N sulphuric acid was taken. Added the molybdate solution and diluted it with washings to a 1 litre with water.

Aminonaphthosulfonic acid reagent : Placed 195 ml of 15 percent sodium bisulfite solution in a glass stoppered cylinder. Added 0.5 g of 1, 2, 4-amino-napthosulfonic acid. Added 5 ml of 20 percent sodium sulfite. Stoppered and shook until the powder was dissolved. If the solution was not not complete, added more sodium sulfite, 1 ml at a time, with shrinkage, but avoiding an excess. Transferred the solution to a brown glass bottle stored in the cold. This solution is usable for about four weeks, if kept in dark.

15 percent sodium bisulfite : To a 30 g of reagent grade sodium bisulfite in a beaker added 200 ml of water from graduated cylinder. Stirred to dissolve and allowed to stand well. Stoppered for several days and filtered.

20 percent sodium sulfite : Dissolved 20 gm of reagent grade anhydrous sodium sulfite in water, diluted to 100 ml, and filtered. Kept well stoppered.

Standard phosphate solution : Dissolved exactly 0.351 gm of pure dry monopotassium phosphate in water, and transferred quantitatively to 1 litre valumetric flask. Added 10 ml of 10 N sulfuric acid, diluted to the mark with water and mixed.

This solution contains 0.4 mg of phosphorus in 5 ml. It is stable indefinitely.

PROCEDURE : 10 mg of dry tissue was taken and homogenised thoroughly after adding 10 ml of 10 percent trichloroacetic acid. Then this was filtered through a low-ash filter paper. Transferred 5 ml of the filtrate to a graduated 10 ml test tube and added 1 ml of the molybdate. After mixing thoroughly, 0.4 ml of aminonaphthosulfonic acid reagent was added and again mixing was done and allowed to stand for 5 minutes. Transferred a portion of the coloured solution to a suitable container and read in the photometer at 660 nm. The photometer was set to zero density with a blank prepared by treating 5 ml of 10 percent trichloroacetic acid with 1 ml of molybdate solution and 0.4 ml of aminonaphthsulfonic acid reagent, followed by water to a volume of 10 ml. Established the density of a standard phosphate solution as follows : Transfer 5 ml of the stock phosphate standard containing 0.4 mg of P, to a 50 ml of volumetric flask, made upto volume with 10 percent trichloroacetic acid, and mixed. Transfer 5 ml of this dilute standard, containing 0.04 mg of phosphorus, to a suitable container, added 1 ml of molybdate solution and 0.4 ml of aminonaphthosulfonic acid reagent, diluted to 10 ml with water and mixed. Allowed to stand 5 minutes and determined the density in the photometer whose zero was set with a blank as described

above.

$$\text{Calculation : } \frac{\text{Density of unknown}}{\text{Density of standard}} \times 0.04 \times 100 = \text{mg inorganic P/100 mg.}$$

The values were expressed as mgm of inorganic phosphate per 100 mg of dry tissue.

RESULTS

RELATION BETWEEN RNA AND DNA CONTENTS IN OYSTERS

The relationship between the RNA and DNA contents is represented in Fig. 22. The RNA content of the whole body of oysters was very low during April 1981, and thereafter it showed a steep increase till the end of June and thus a primary peak was observed during this period. The DNA content on the other hand, showed a declining trend from the month of May 1981. During April, the DNA content showed the maximum value estimated at 0.211 mg/100 mg of dry tissue. The declining trend of DNA content was very sharp and it falls to the lowest level in the subsequent months till July 1981. The lowest value recorded during this period was 0.068 mg/100 mg, during July.

The RNA content which was found at its peak level during June showed a declining trend slowly in the month of July and August, and in the subsequent month it fell

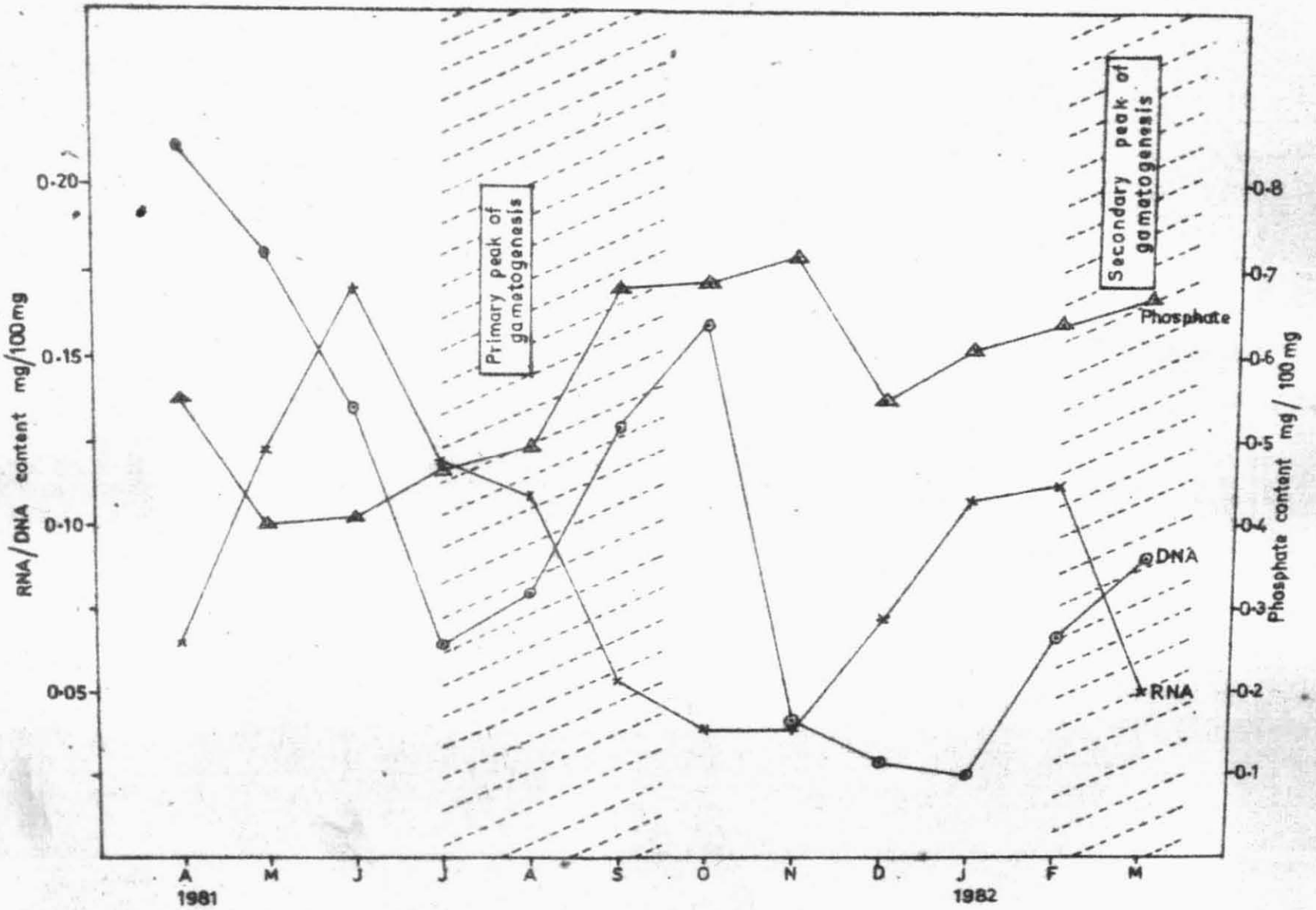


Fig. 22 RNA, DNA and Phosphate contents of the oyster, C. madrasensis during April 1981 — March 1982.

very sharply. This is mainly due to the utilization of RNA material during the period of maturation of gametes. The DNA content was shown a gradual increase from the month of July and showed its maximum in the month of October indicating the full ripeness of the gonads during the peak period of maturation. Thus the RNA and DNA contents showed a reciprocal relationship in the body of the oysters i.e., whenever the RNA content was high, the DNA content was very low or vice-versa. The same trend of relationship was observed during the second peak of reproduction also. Quantitatively, the DNA content is higher than the RNA content in the whole body of oysters.

The phosphate content also showed fluctuations in its abundance but when compared to the nucleic acids, it is very feeble. The peak in phosphate content was observed in April, thereafter it falls till June. Again it showed an increasing trend from the month of July to October as the reproductive elements showed their progress in growth. Thus the phosphorus showed a similar trend as in the case of the DNA content of the oysters.

RNA, DNA AND INORGANIC PHOSPHATE CONCENTRATIONS IN RELATION TO SEX

RNA, DNA and Phosphate contents in the oysters were studied separately for both the male and the female oysters to find out the variations, if any, among the sexes. Though there are some minor variations in the quantity of RNA, DNA and Phosphate contents between the male and female oysters, the statistical applications have shown that these differences are not significant. Hence the data of both the sexes was pooled together to find out their variations seasonally and their relation to the various stages of reproduction and intensity of feeding, etc.,.

SEASONAL VARIATIONS IN RNA, DNA AND INORGANIC PHOSPHATE.

There were marked differences in the RNA, DNA and phosphate contents during the different seasons of the year which determine the physiology of reproduction, growth, and feeding etc.,. They are illustrated in fig. 23-25.

During the summer months (April, May and June) a remarkable variation in the RNA content was observed. During the month of April, the RNA content showed a very low value and then a steep increase was observed in the month of May and attained the primary peak in June '81.

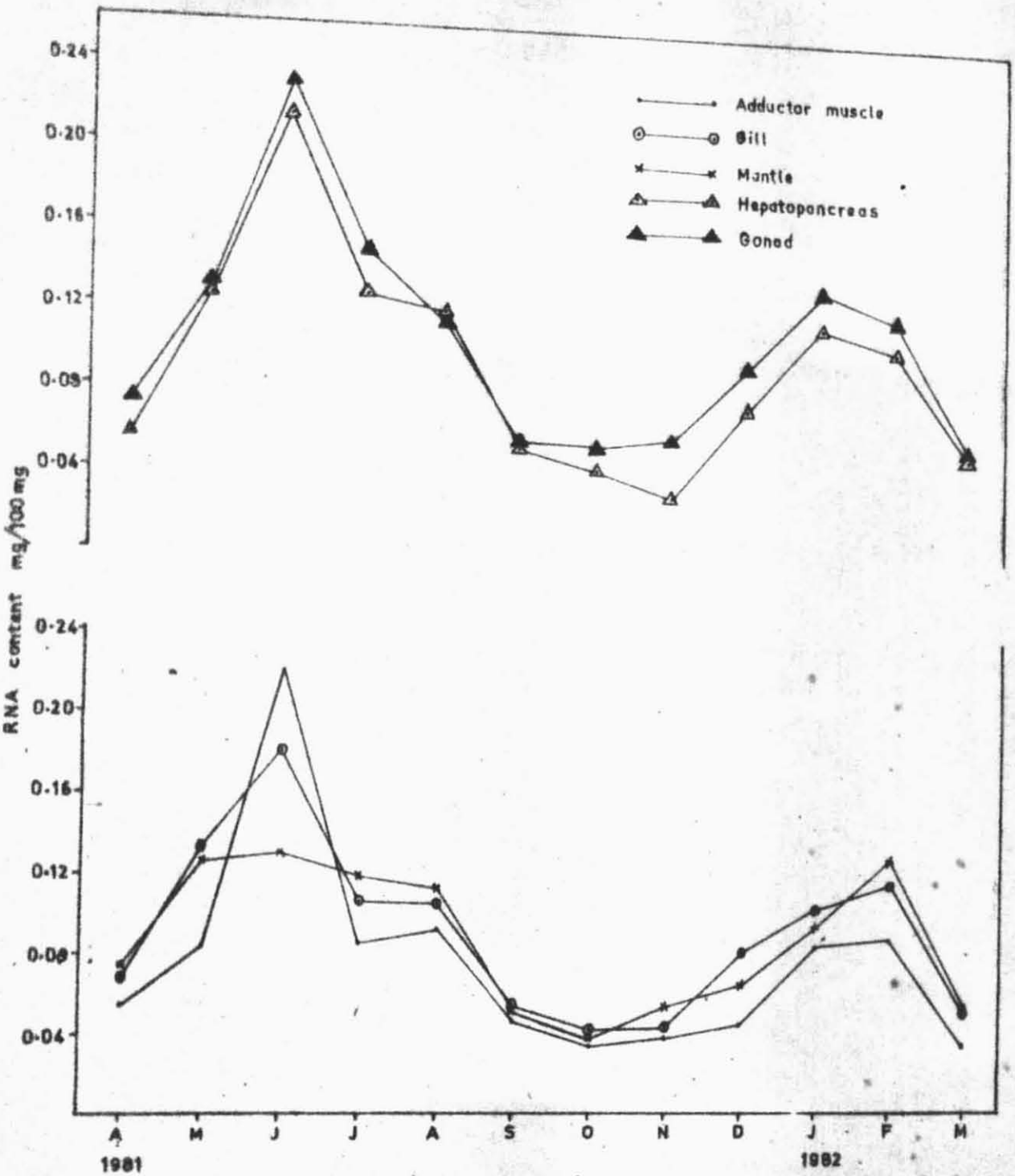


Fig. 23 RNA content of the body components of C. madrasensis during April, 1981—March, 1982.

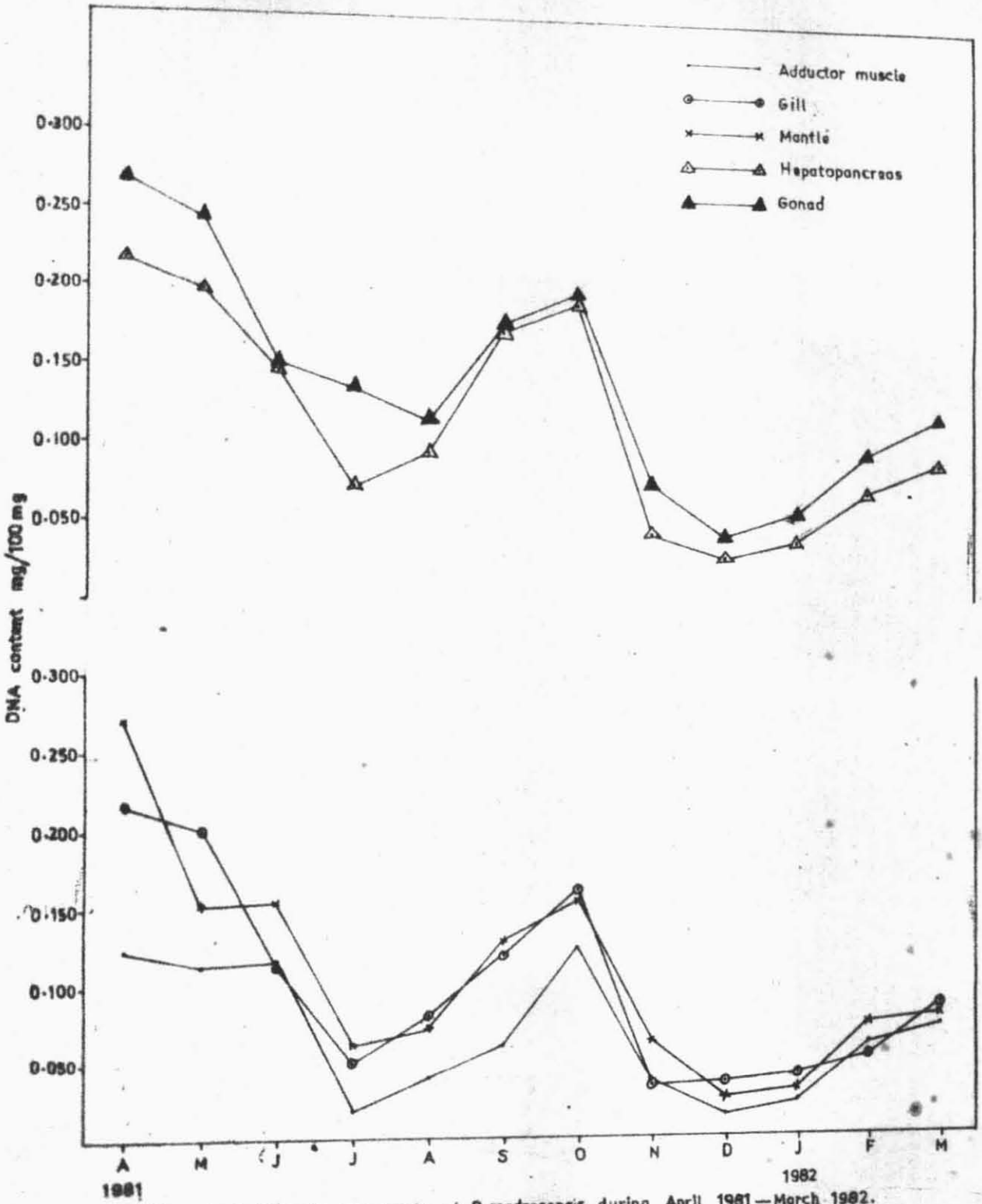


Fig. 24 DNA content of the body components of C. madrasensis during April 1981 — March 1982.

The DNA and inorganic phosphate contents of the oysters had more or less similar trends during the summer months. During April, the DNA content was at its peak and fell very sharply during the month of May and was noted to continue at the same level till July. The phosphate content had fallen very sharply from the month of April to May, and in the subsequent months, there was a very feeble rise in the quantity of the phosphate. This may be attributed to the higher intensity of feeding immediately after spawning.

During the pre-monsoon months of July, August and September, remarkable changes were observed to occur in all the three constituents. The RNA content which was built up during the previous season was found to decline very rapidly from the month of July to September and this is suggested to be utilised in protein synthesis during the period of gametogenesis. The DNA content which was found to be very low in the oysters during July showed an increasing trend till the end of the pre-monsoon, as a result of multiplication and growth of the reproductive elements. The phosphate content which showed a gradual rise during the summer months showed further increase from June to July. Again an increase was observed from July to August and once again it increased to higher levels from August to September.

Usually the monsoonal rain starts in the month of October extending upto December and the salinity of the

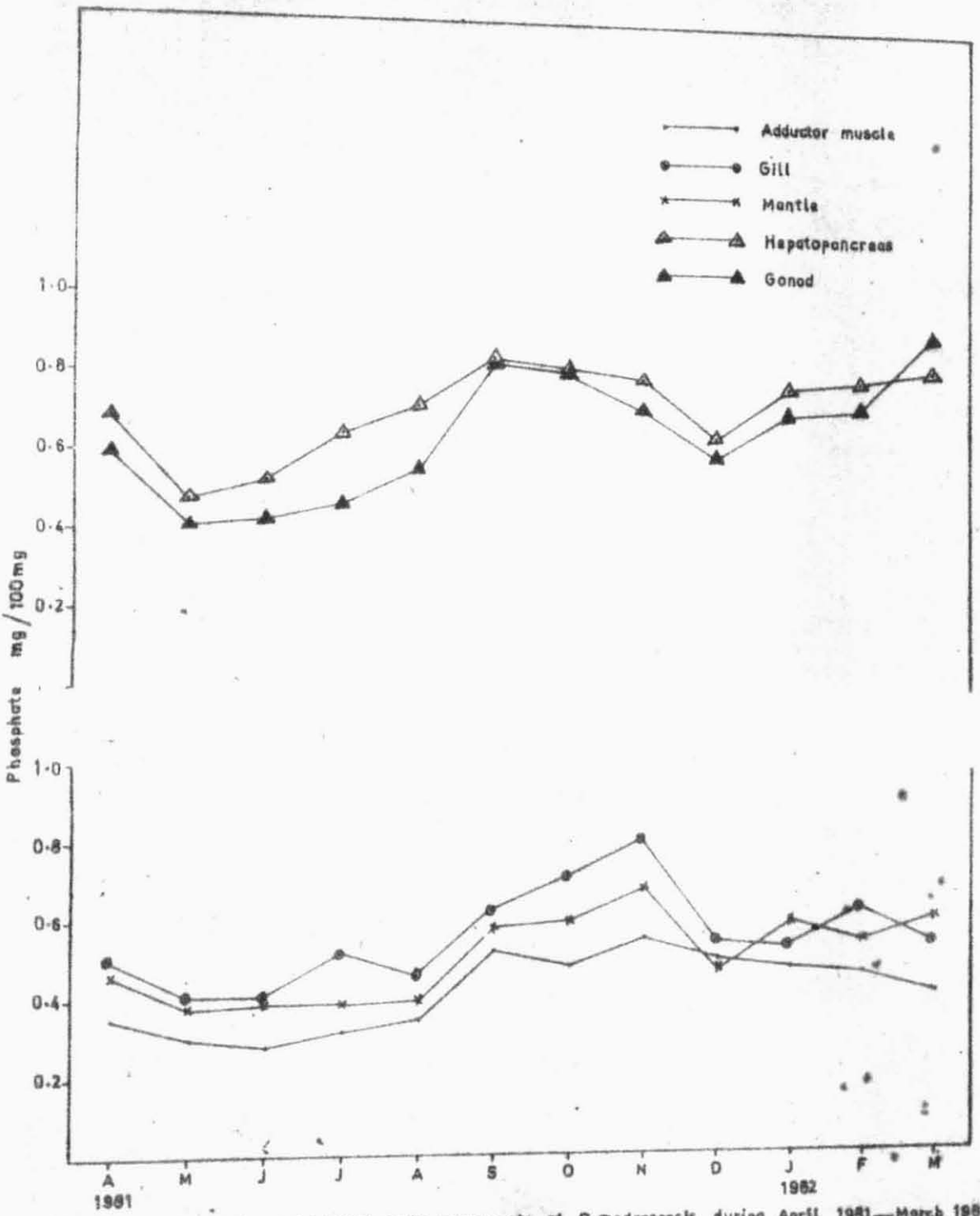


Fig. 25 Phosphate content of the body components of C.madrasensis during April 1981—March 1982

lake declines considerably which influences both the biochemical and the physiological status of the oysters. The RNA content was observed to be very low in October, when the oysters were in the fully ripe condition. The oysters have spawned in the second half of October, as a result of the lowering in salinity. In the subsequent month, there was a very slow increase in the RNA content of oysters and in the month of December 1981, there was a steep rise in the RNA content. The DNA content which was found at a peak during the month of October appears to fall sharply indicating the spawning of oysters during this period. The DNA content continued to decline till December. The phosphate content was maintained at a peak level during October and November and decreased sharply in the month of December 1981. Thus there was a fall and rise in RNA content but a corresponding peak and depression in the case of DNA and phosphate contents of oysters.

The post-monsoon is characterised by a corresponding increase in the salinity and restoration of the oysters to the pre-monsoon physiological condition. RNA content had shown a peak during January and February and thereafter it had fallen very sharply to a very low level due to the onset of gametogenesis for the second peak. The DNA content was found to increase from January to March considerably coinciding with the second gametogenesis during this period. The increase of phosphate content was very feeble

from January to March.

Thus the RNA showed two peaks, the primary one in June-July and the secondary one in January-February. The DNA and phosphate contents have shown their primary peak during the month of October and the secondary one during the month of April.

QUANTITATIVE CHANGES OF RNA, DNA AND PHOSPHATE CONTENTS IN DIFFERENT BODY COMPONENTS

Monthly variations in the quantity of RNA, DNA and phosphate content in the five different body components are given in Tables 22, 23 & 24. All the body components such as mantle, gill, adductor muscle, hepatopancreas and gonad showed the lowest level of concentration of RNA during the month of April. Among all the above tissues, the lowest concentration of RNA was observed in the adductor muscle (0.054 mg/100 mg). In the hepatopancreas the RNA content was 0.057 mg/100 mg; in mantle, gill and gonad it was observed to be 0.075 mg, 0.068 mg and 0.073 mg/100 mg respectively. A rise in the RNA content was registered in all the body components during the month of June 1981. The adductor muscle, gonad and hepatopancreas showed a maximum of 0.221 mg, 0.231 mg and 0.214 mg/100 mg of tissue respectively. The mantle has a very low RNA content during the month of June compared to the other body components.

Table. 22

RNA (mg/100 mg) content of body components of 101-120 mm size group of C. madrasensis during April 1981-March 1982; each value represents the average estimate of 8 samples (Mean ± S.D).

Month & Year	Mantle	Gill	Adductor muscle	Hepatopancreas	Gonad
April 1981	0.075 ± 0.003	0.068 ± 0.003	0.054 ± 0.002	0.057 ± 0.004	0.073 ± 0.006
May	0.127 ± 0.002	0.113 ± 0.003	0.083 ± 0.003	0.127 ± 0.003	0.129 ± 0.003
June	0.130 ± 0.005	0.181 ± 0.003	0.221 ± 0.004	0.214 ± 0.005	0.234 ± 0.003
July	0.119 ± 0.003	0.106 ± 0.003	0.086 ± 0.002	0.127 ± 0.004	0.148 ± 0.006
August	0.113 ± 0.006	0.105 ± 0.002	0.094 ± 0.002	0.119 ± 0.003	0.116 ± 0.003
September	0.053 ± 0.002	0.054 ± 0.002	0.048 ± 0.001	0.052 ± 0.004	0.054 ± 0.001
October	0.039 ± 0.002	0.041 ± 0.002	0.036 ± 0.001	0.043 ± 0.003	0.053 ± 0.001
November	0.054 ± 0.001	0.043 ± 0.002	0.039 ± 0.003	0.029 ± 0.004	0.058 ± 0.002
December	0.066 ± 0.002	0.081 ± 0.002	0.046 ± 0.003	0.073 ± 0.001	0.091 ± 0.003
January 1982	0.095 ± 0.001	0.103 ± 0.003	0.087 ± 0.001	0.117 ± 0.002	0.134 ± 0.003
February	0.129 ± 0.002	0.116 ± 0.001	0.089 ± 0.003	0.106 ± 0.001	0.120 ± 0.003
March	0.055 ± 0.002	0.055 ± 0.001	0.036 ± 0.001	0.053 ± 0.001	0.054 ± 0.004

In the month of July, the RNA content showed a declining trend in all the body components. The gonad showed a higher concentration than the other body components during July 1981. The concentration of RNA was more or less maintained at a constant level in all the body components except for a gradual decline in the gonad during August. This decline may be due to the utilization of RNA in protein synthesis during the period of gametogenesis. Again there was a sharp decline observed in all the body components during the period between August to October. During the month of November and December there was a gradual increase in RNA concentration in all the other body components except in the hepatopancreas in which the RNA concentration has shown furthermore decline from October to November and thereafter it started to rise again.

During the month of January and February 1982, there was another minor peak in the concentration of RNA and thereafter it started to decline rapidly as a result of maturation of gonads for the second peak of the reproductive cycle.

Almost in all the months of the year the RNA concentration in the adductor muscle was observed to be lower than in the other body components except during the month of June. The mantle registered a slightly higher concentration than the adductor muscle. The fluctuation in the

Table. 23

DNA (mg/100 mg) content of body components of 101-120 mm size group of C. madrasensis during April 1981-March 1982; each value represents the average estimate of 8 samples (Mean ± S.D).

Month & Year	Mantle	Gill	Adductor muscle	Hepatopancreas	Gonad
April 1981	0.271 ± 0.007	0.217 ± 0.007	0.122 ± 0.005	0.219 ± 0.002	0.266 ± 0.003
May	0.152 ± 0.002	0.202 ± 0.007	0.113 ± 0.003	0.198 ± 0.007	0.245 ± 0.005
June	0.154 ± 0.004	0.114 ± 0.003	0.114 ± 0.003	0.147 ± 0.006	0.147 ± 0.006
July	0.063 ± 0.002	0.051 ± 0.001	0.020 ± 0.001	0.072 ± 0.003	0.136 ± 0.002
August	0.071 ± 0.001	0.079 ± 0.003	0.040 ± 0.006	0.095 ± 0.003	0.113 ± 0.002
September	0.131 ± 0.001	0.121 ± 0.002	0.063 ± 0.001	0.173 ± 0.005	0.174 ± 0.002
October	0.155 ± 0.001	0.159 ± 0.005	0.120 ± 0.004	0.191 ± 0.003	0.194 ± 0.194
November	0.062 ± 0.002	0.031 ± 0.001	0.033 ± 0.001	0.042 ± 0.003	0.072 ± 0.002
December	0.026 ± 0.001	0.034 ± 0.007	0.014 ± 0.001	0.027 ± 0.003	0.039 ± 0.001
January 1982	0.029 ± 0.001	0.039 ± 0.001	0.022 ± 0.001	0.037 ± 0.002	0.054 ± 0.003
February	0.075 ± 0.003	0.052 ± 0.001	0.059 ± 0.003	0.071 ± 0.004	0.090 ± 0.002
March	0.086 ± 0.003	0.087 ± 0.001	0.073 ± 0.005	0.088 ± 0.001	0.118 ± 0.004

RNA concentration were of a similar pattern in all the other tissues. The hepatopancreas and gonad showed a similar trend in their fluctuations. The gonad registered a higher DNA concentration than the hepatopancreas during the entire period of study. A very low concentration of 0.029 mg/100 mg, was observed in the hepatopancreas during the month of November 1981.

The RNA concentration has shown a similar trend in all the body components. The major fluctuations in the RNA concentrations were observed in the gonad and in the hepato pancreas. The concentrations in the gonad and the hepatopancreas have shown more or less a parallel sequence throughout the period of observation.

The peak period of DNA was observed in the month of April in all the body components, thereafter it showed a declining trend till the first half of July '81. The mantle had shown a concentration higher than the adductor muscle and the gill. The lowest concentration of DNA was noticed in the adductor muscle. The hepatopancreas and gonad registered a similar trend as in the case of the other tissues. The gonad showed the maximum concentration of RNA during this period. In all body components, the DNA content increased again from the month of July and reached a peak during the month of October, when the oysters were found in the fully ripe condition. Mantle and gill showed almost

Table. 24.

Inorganic phosphate (mg/100 mg of dry tissue) content of body components of 101-120 mm size group of C. madrasensis during April 1981-March 1981; each value represents the average estimate of 8 samples (mean ± S.D).

Month & Year	Mantle	Gill	Adductor muscle	Hepatopancreas	Gonad
April 1981	0.4589 ± 0.019	0.4837 ± 0.040	0.3508 ± 0.005	0.6729 ± 0.009	0.5923 ± 0.020
May	0.3808 ± 0.006	0.4039 ± 0.015	0.3064 ± 0.004	0.4898 ± 0.015	0.4244 ± 0.009
June	0.3974 ± 0.003	0.4051 ± 0.005	0.2872 ± 0.006	0.5218 ± 0.003	0.4320 ± 0.023
July	0.3911 ± 0.034	0.5156 ± 0	0.3200 ± 0	0.6400 ± 0.003	0.4823 ± 0.025
August	0.4029 ± 0.028	0.4593 ± 0.012	0.3526 ± 0.020	0.7053 ± 0.006	0.5541 ± 0.035
September	0.5895 ± 0.000	0.6292 ± 0.005	0.5333 ± 0.003	0.8375 ± 0.020	0.8292 ± 0.050
October	0.6042 ± 0.017	0.7084 ± 0.014	0.4867 ± 0,003	0.8250 ± 0.010	0.8042 ± 0.0[illegible]
November	0.6882 ± 0.015	0.8134 ± 0.003	0.5591 ± 0.007	0.7936 ± 0.045	0.7[illegible] ± 0.[illegible]
December	0.4882 ± 0.018	0.5505 ± 0.050	0.5073 ± 0.024	0.6452 ± 0.020	0.5936 ± 0.040
January 1982	0.6118 ± 0.035	0.5471 ± 0.060	0.4824 ± 0.010	0.7707 ± 0.035	0.7030 ± 0.030
February	0.5608 ± 0.035	0.6453 ± 0.045	0.4745 ± 0.027	0.7981 ± 0.035	0.7225 ± 0.030
March	0.6235 ± 0.040	0.5530 ± 0.039	0.4275 ± 0.060	0.8137 ± 0.045	0.7137 ± 0

the same condition as the gonad and hepatopancreas during the month of November. Immediately after spawning, the DNA concentration decline considerably to the lowest level in all the body components. Again from the month of January, it began to rise gradually in all the body components for the second reproductive peak. This rise was observed till the end of April.

The DNA concentration was at an elevated level in the gonads when compared to the other body components throughout the period of study. The hepatopancreas has registered a similar trend but slightly lower in quantity than the gonad. The adductor muscle has shown very low concentration during the entire period of observation. The gill and mantle have shown more or less equal concentrations.

The fluctuations in the phosphate content were feeble and do not appear silimar to the RNA and DNA. The phosphate content was high in April in all the body components and thereafter gradually decreasing till June. Again there was a gradual rise in the inorganic phosphate content in all the body components from July to November coinciding with the maturation of oysters. Soon after the spawning, there was a decrease in the inorganic phosphate content in all the body components. The adductor muscle showed low values during the subsequent months. The phosphate content in the mantle, gill, hepatopancreas and gonad gradually

increased to a higher level and attained a peak in April.

Adductor muscle has the lowest concentration of phosphate throughout the period of study when compared to all the other body components. The fluctuations in this particular tissue were very feeble. The phosphate content in the mantle was higher than that of the adductor muscle. Gill registered a higher concentration of phosphate content.

Among the five different body components, the hepatopancreas had the highest concentration of phosphate. The gonad had a lower concentration of phosphate when compared to the hepatopancreas.

RNA, DNA AND INORGANIC PHOSPHATE CONTENT IN RELATION TO REPRODUCTION.

There is a considerable variation in the RNA, DNA and inorganic phosphate contents, especially in the gonad and in the hepatopancreas, during the various stages of reproduction(Table. 25). The concentrations of the above components have been observed to vary in different body components and this is mainly assumed to be due to the various metabolic activities in the tissue and which transfer energy during the period of maturation of the gametes.

RIBONUCLEIC ACID

The changes occurring in the RNA content at different stages of the gonadial maturity of the oysters are

Table. 25.

Quantitative changes of RNA, DNA and Inorganic phosphate content (mg/100 mg of dry tissue) during the different stages of gonad of *C. madrasensis*; each value represents the average estimate of 8 samples (mean ± S.D).

Biochemical component	Body component	Stages of gonad I	II	III	IV	V	VI	VII	VIII
RNA	Mantle	0.119 ± 0.002	0.113 ± 0.006	0.053 ± 0.003	0.055 ± 0.001	0.054 ± 0.001	0.097 ± 0.001	0.125 ± 0.001	0.074 ± 0.001
	Gill	0.106 ± 0.002	0.095 ± 0.004	0.054 ± 0.002	0.056 ± 0.001	0.043 ± 0.002	0.106 ± 0.002	0.129 ± 0.003	0.077 ± 0.001
	Adductor muscle	0.085 ± 0.002	0.094 ± 0.002	0.048 ± 0.001	0.045 ± 0.002	0.039 ± 0.003	0.059 ± 0.004	0.089 ± 0.003	0.100 ± 0.001
	Hepato-pancreas	0.127 ± 0.004	0.109 ± 0.003	0.055 ± 0.001	0.052 ± 0.003	0.029 ± 0.004	0.086 ± 0.001	0.114 ± 0.002	0.115 ± 0.001
	Gonad	0.148 ± 0.006	0.116 ± 0.003	0.056 ± 0.001	0.044 ± 0.002	0.058 ± 0.002	0.101 ± 0.004	0.121 ± 0.002	0.135 ± 0.003
DNA	Mantle	0.056 ± 0.003	0.072 ± 0.001	0.131 ± 0.003	0.242 ± 0.002	0.077 ± 0.003	0.026 ± 0.002	0.094 ± 0.001	0.027 ± 0.002
	Gill	0.071 ± 0.005	0.067 ± 0.001	0.121 ± 0.004	0.244 ± 0.002	0.059 ± 0.001	0.034 ± 0.001	0.089 ± 0.002	0.020 ± 0.001
	Adductor muscle	0.038 ± 0.007	0.027 ± 0.002	0.063 ± 0.006	0.121 ± 0.002	0.054 ± 0.002	0.051 ± 0.002	0.063 ± 0.002	0.016 ± 0.001
	Hepatopan-creas	0.056 ± 0.004	0.103 ± 0.001	0.172 ± 0.004	0.231 ± 0.004	0.077 ± 0.004	0.027 ± 0.001	0.140 ± 0.006	0.023 ± 0.002
	Gonad	0.081 ± 0.001	0.129 ± 0.003	0.174 ± 0.002	0.261 ± 0.006	0.122 ± 0.004	0.039 ± 0.005	0.111 ± 0.030	0.037 ± 0.001
Phosphorus	Mantle	0.391 ± 0.022	0.477 ± 0.016	0.589 ± 0.020	0.605 ± 0.046	0.459 ± 0.019	0.488 ± 0.004	0.612 ± 0.080	0.465 ± 0.002
	Gill	0.515 ± 0	0.619 ± 0.034	0.629 ± 0.005	0.747 ± 0.022	0.484 ± 0.040	0.551 ± 0.006	0.547 ± 0.045	0.637 ± 0.050
	Adductor muscle	0.320 ± 0	0.392 ± 0.025	0.533 ± 0.002	0.536 ± 0.035	0.351 ± 0.055	0.465 ± 0.003	0.482 ± 0.010	0.520 ± 0.028
	Hepatopan-creas	0.640 ± 0.034	0.682 ± 0.050	0.838 ± 0.006	0.884 ± 0.075	0.686 ± 0.060	0.645 ± 0.020	0.844 ± 0.035	0.643 ± 0.020
	Gonad	0.462 ± 0.025	0.591 ± 0.025	0.811 ± 0.005	0.829 ± 0.025	0.655 ± 0.004	0.504 ± 0.030	0.652 ± 0.003	0.644 ± 0.050

illustrated in Fig. 26. The DNA content was found to be at an elevated level in the gonad and slightly at a lower level in the hepatopancreas during the I stage. The mantle, gill and adductor muscle also showed higher concentrations during this period. The RNA content observed during this period were 0.119 mg, 0.106 mg, 0.085 mg, 0.125 mg and 0.148 mg/100 mg of dry tissue of mantle, gill, adductor muscle, hepatopancreas and gonad respectively. During the II stage, all the tissues except the adductor muscle showed a feeble decline, indicating a further growth of the reproductive elements.

Growth of the oocytes in the III stage was rapid and this stage has been characterised by the presence of a long peduncle in the oocytes of females and in the secondary spermatocytes of males. Low quantities of RNA such as 0.054 mg, 0.055 mg, 0.048 mg, 0.054 mg and 0.053 mg per 100 mg of gonad, hepatopancreas, adductor muscle, gill and mantle were recorded respectively. In the IV stage, (Ripe oysters with rounded ova and a stream of spermatozoa) the RNA content has shown that there were no remarkable changes in the tissue except in the hepatopancreas and in the gonad in which further decrease was observed during this period. The V stage of the gonad was characterised by the presence of a few ova in the females and a partial shrinkage of follicles in the males respectively, and during this period, the RNA content has shown remarkable variations in the

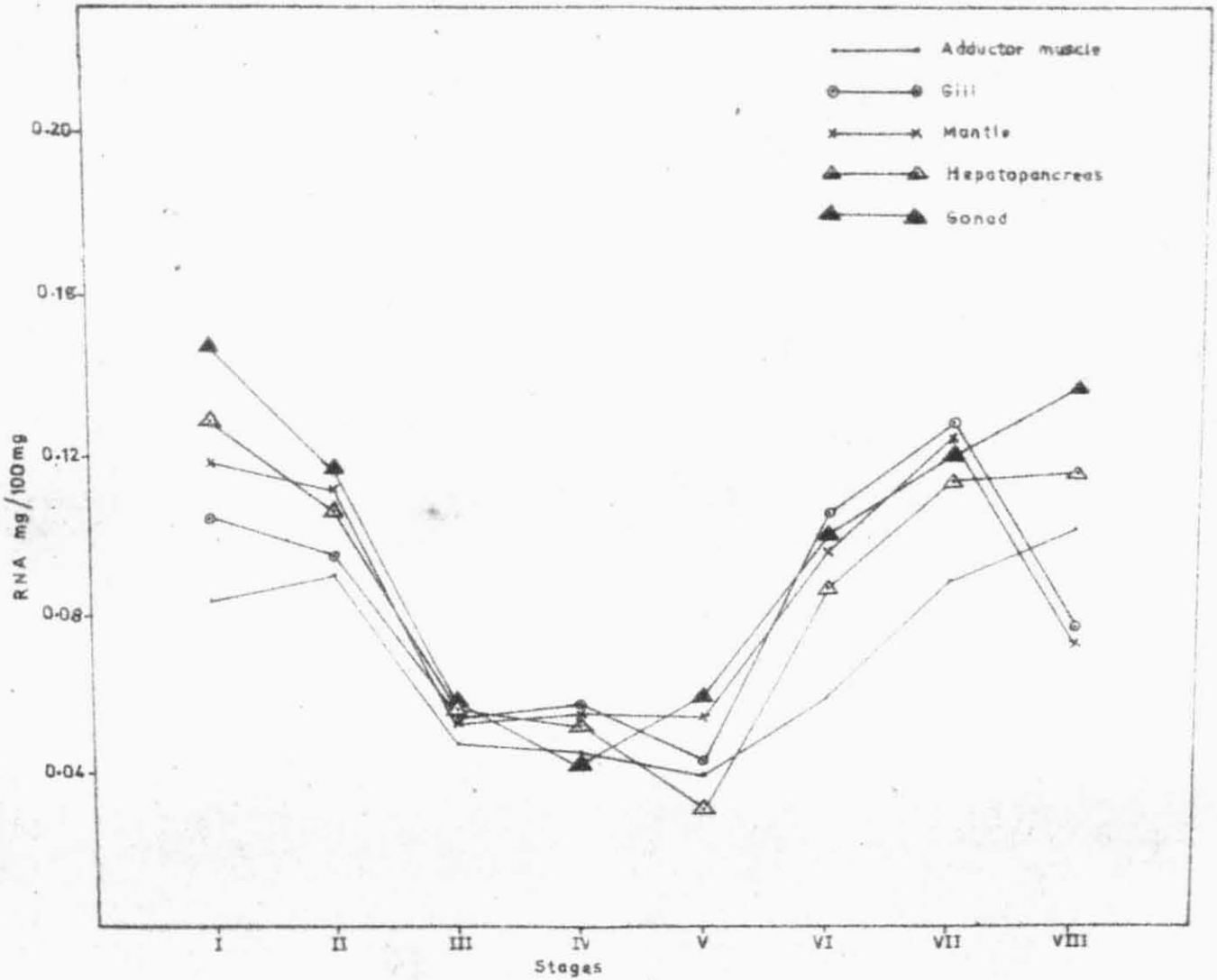


Fig. 26 RNA content of the different stages of the gonad of the oyster, C. madrasensis.

mantle, gill and the adductor muscle, whereas there was a feeble rise in the gonad. The VI stage is represented by a gonad in which the follicles are shrunken to a large extent and when the phagocytic cells make their appearance. The RNA content during this stage showed an increasing trend from a lower level. The VII stage is characterised by the regressive condition of the oysters during which period autolysis and resorption of unspawned reproductive elements took place. During this period the concentration of RNA slowly increased in all the tissues. The VIII stage is the indeterminate stage in which the RNA content has registered a very high concentration.

DEOXYRIBONUCLEIC ACID

The variations in DNA content of oysters at different stages of the gonad are illustrated in Fig. 27. During the I stage the DNA contents in the mantle, gill, adductor muscle, hepatopancreas and gonad were 0.0565 mg, 0.071 mg, 0.038 mg, 0.056 mg and 0.081 mg per 100 mg of tissue respectively. The DNA content which was low in the I stage, showed a slight increase in the mantle, hepatopancreas and gonad whereas in the adductor muscle and gill it registered a small reduction in the DNA content during the II stage. In the III stage, all the body components have shown an increasing trend in the in the DNA content. In the concentration of DNA, the hepatopancreas has shown

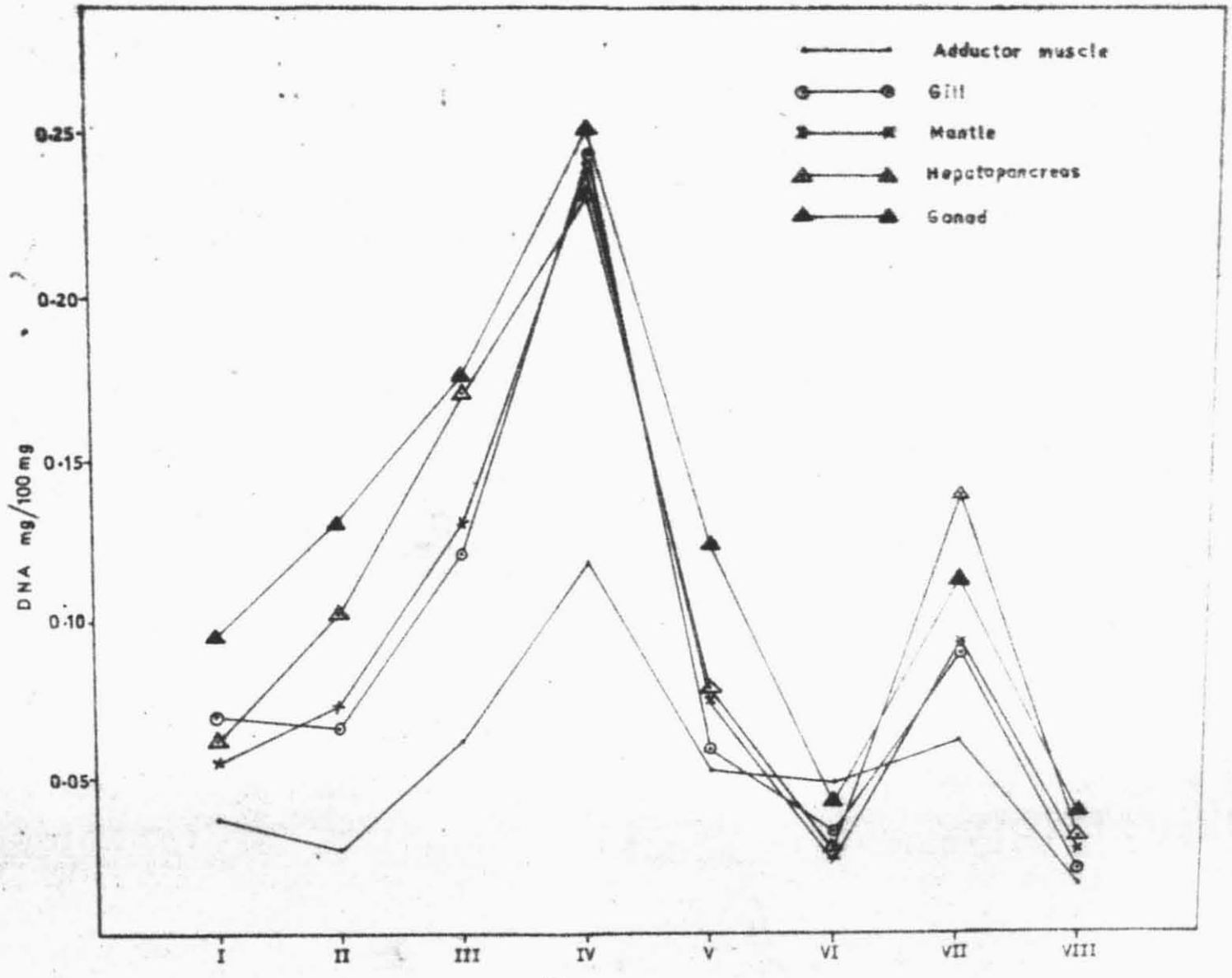


Fig. 27 DNA content at the different stages of the gonad of the oyster, C. madrasensis

a steep increasing trend than in the gonad, during this period. In the IV stage again, there was a considerable increase in the concentration of all the body components. The gonad registered a very high peak in the DNA concentration during this stage, whereas the gilland mantle showed a slightly lesser DNA than the gonad. The concentration of DNA in the hepatopancreas was lower than in the other three tissues. During the IV stage, the concentration of DNA was observed to be 0.242 mg, 0.244 mg, 0.121 mg, 0.231 mg and 0.261 mg per 100 mg of dry tissue of the mantle, gill, adductor muscle, hepatopancreas and gonad respectively. In the V stage there was a sharp fall of DNA in all the body components. This fall was found to continue till the VI stage, but the fall was found to be conspicuous. During this stage the DNA content of all tissues comes to a common very low level indicating the inactive condition of the gonad. During the VII stage, the DNA content of the gonad was reduced to a considerable amount as a result of autolysis and resorption into the body and this reduction was reflected by the hike in the DNA concentration in hepatopancreas, whereas all other tissues including the gonad showed lower concentration of DNA. In the indeterminate stage(VIII) again the concentration falls to a common low level in all the tissues.

INORGANIC PHOSPHATE

The phosphate content in the different body components of the oyster is illustrated in Fig. 28. During the I stage, the inorganic phosphate concentration in all the body components was found to be very low. The concentration of phosphate was estimated to be 0.3911 mg, 0.5154 mg, 0.32 mg, 0.64 mg and 0.4623 mg per 100 mg in the mantle, gill, adductor muscle, hepatopancreas and gonad respectively. There was a gradual increase in the concentration in all the tissues during the II stage. In the III stage, the phosphate concentration was found to increase furthermore in all the body components, including in the gonad, but the gonad was observed to be building up phosphate very fast, indicating a very fast growth of gametes from the II to the III stage. In the IV stage, the progress in the phosphate concentration was very slow and the same was observed in all the other tissues also. At the ripe condition, the phosphate content was observed to be 0.6048 mg, 0.7467 mg, 0.536 mg, 0.8843 mg and 0.8292 mg per 100 mg of mantle, gill, adductor muscle, hepatopancreas and gonad respectively. There was a remarkable decrease in the phosphate content in all the tissues at stage V, due to the extrusion of sex products during this stage. In the VI stage, as a result of the completion of spawning, the phosphate content of the gonad and hepatopancreas again showed a decreasing trend, but in the tissues such as gill,

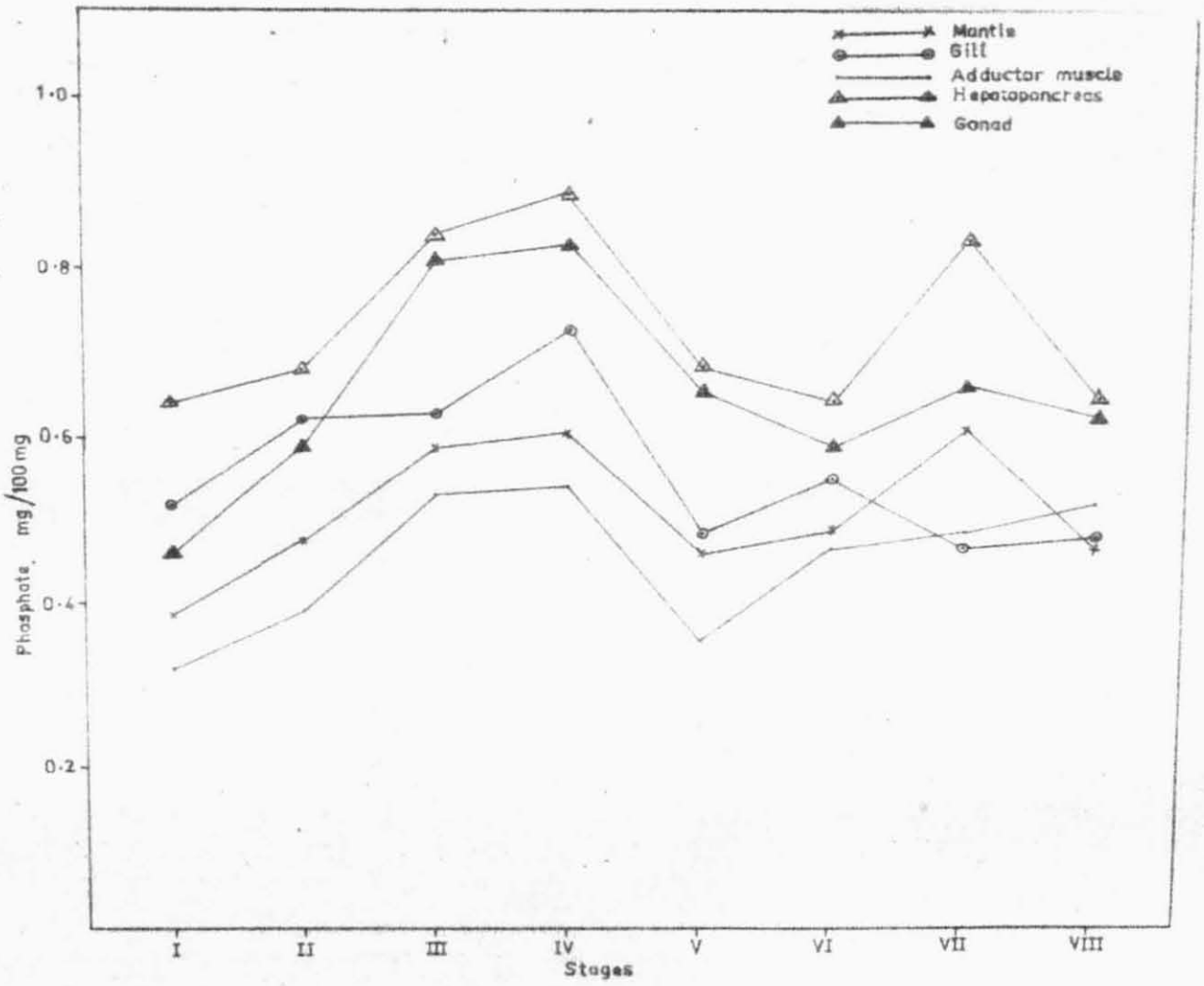


Fig. 28 Phosphate content at the different stages of the gonad of the oyster, C. madrasensis.

mantle and adductor muscle it showed an increasing trend. During the period of regression (VII stage), the phosphate content showed slightly higher level than in the VI stage. The concentration of the phosphate in the gonad was observed to be low, but in the hepatopancreas there was a considerable hike in the concentration of phosphate, indicating the resorption from the gonads. In the VIII stage considerably low concentration of phosphate was observed in all the tissue components. The phosphate content of the gonad and hepatopancreas came to a common level during this period. The other body components also showed a more or less common low level of phosphate.

RNA, DNA AND PHOSPHATE CONCENTRATIONS IN RELATION TO FEEDING INTENSITY

Based on the gut content analysis of the oyster, two peaks of high intensity of feeding were observed, one during December-January and the other May-June, coinciding with the two peaks of RNA concentration. Low intensity of feeding was observed during August, October, November '81 and February '82. During the month of August, 1981 there was a sharp reduction in the RNA content of the gonad and hepatopancreas and also due to poor feeding there was no remarkable changes in all the other body components such as mantle, gill and adductor muscle.

In the month of October-November, the RNA content in all the body components showed the lowest levels, and in the hepatopancreas also there was a further decrease in all the body components indicating almost the depletion of RNA during this period.

A major peak of RNA content was noticed during the month of June. During this month, all the body components showed a peak level and in the subsequent month there was a sudden fall indicating their utilization for gametogenesis. The two peaks of high intensity of feeding coincided with the corresponding two peaks of RNA, followed by the ripening of gametes.

A minor peak of RNA concentration was observed during January-February. During the month of January all the body components showed an elevated level of RNA. This hike was reduced to a low level in the month of February, especially in the gonad and hepatopancreas due to low intensity of feeding.

During the two peaks of high intensity of feeding coinciding with the two peaks of RNA, the DNA concentration was very low. The lowermost level of DNA concentration was found in all the tissues during December-January; and in the month of May-June, it was found decreasing in the gonad, hepatopancreas and gill. It was more or less maintained at a constant level in the mantle and in the

adductor muscle. The low intensity of feeding during August was indicated by a very low progress of DNA content in all the tissues, but the gonad showed a reduction in the DNA content during this period. During the month of October-November, as a result of spawning, the DNA content, along with the discharge of the ripe gametes, declines and shows a low level in November. Since the feeding was high in January, the energy required for future use was built ir the form of glycogen which was utilised for the initiation of the gametogenesis during the month of February, even when there was a poor feeding in the oysters compared to the other months. As a result of gametogenesis there was an increasing trend in the DNA concentration in all the body components during the month of February. This trend continues till April when the primary peak was shown in this month.

The phosphate content of the gonad was found to be high in April. As a result of spawning in April, the inorganic phosphate content was very low in all the other body components. Due to high feeding intensity the phosphate content of the gonad and hepatopancreas showed an elevated trend in the month of June. In the remaining tissues such as mantle, gill and adductor muscle, the phosphate level was maintained more or less at a constant level as in the previous month. In the month of December, as a result of loss of gametes during spawning in the previous

month and also due to low intensity of feeding there was a fall in the phosphate content. In January '82 the phosphate content registered an increasing trend in the mantle, hepatopancreas and gonad, whereas in gill and adductor muscle it was almost at a constant level. As a result of moderate feeding and rapid maturation of the reproductive elements, the phosphate content was observed to be high in all the body components during September. Low intensity of feeding was noticed during October-November due to the prevalence of low saline conditions in the lake, as a result of which the phosphate content has shown a declining trend in October-November in both the hepatopancreas and in the gonad, whereas in the other tissues such as mantle, gill and adductor muscle a slight increase was observed. During August 1981 also, there was a slight increase in the concentration of phosphate when compared to the subsequent month. During the month of February'82, the feeding intensity was very low and also this was the period of the onset of gametogenesis. Even though the feeding was poor, the gonad, hepatopancreas and mantle showed a feeble increase in the phosphate content, whereas the gills and adductor muscle showed a slight decrease during this period.

RELATION BETWEEN THE NUCLEIC ACIDS AND THE WET WEIGHT OF OYSTERS

Seasonal variations in the meat weight of oysters of the size 101-120 mm and the DNA content of the various

tissues of that particular size group were correlated for one year(Fig. 29). Totally 254 oysters were weighed and average of 10 to 34 numbers of oysters per month were taken into consideration. During April 1981, the average weight of oysters was found to be high as a result of the fully ripe condition of the oysters and the DNA content also was found to be high during this period. In May, the average weight of the oysters decreased and the DNA content also decreased considerably, and this was mainly due to the liberation of the sex products. In June-July, there was a further decline in the DNA content since the oysters were fully spent and since some of the oysters were undergoing a resting stage. But there was a hike in flesh weight due to heavy feeding, thus not showing any relationship with the weight increase due to feeding. In August, the weight of the flesh increased again, and in September the weight has considerably fallen. The DNA content was found to increase in the tissue components in both the months. This may be due to the commencement of the gametogenesis in the gonad during this period. In January, there was a rise in the weight of the tissue and a feeble rise in the DNA content. Again in February, the feeding was poor but the DNA was found to increase due to gametogenesis in the oysters. On examining the above, it is concluded that the DNA concentration in the oysters increases as a result of maturation of gametes, and during this period oysters have shown

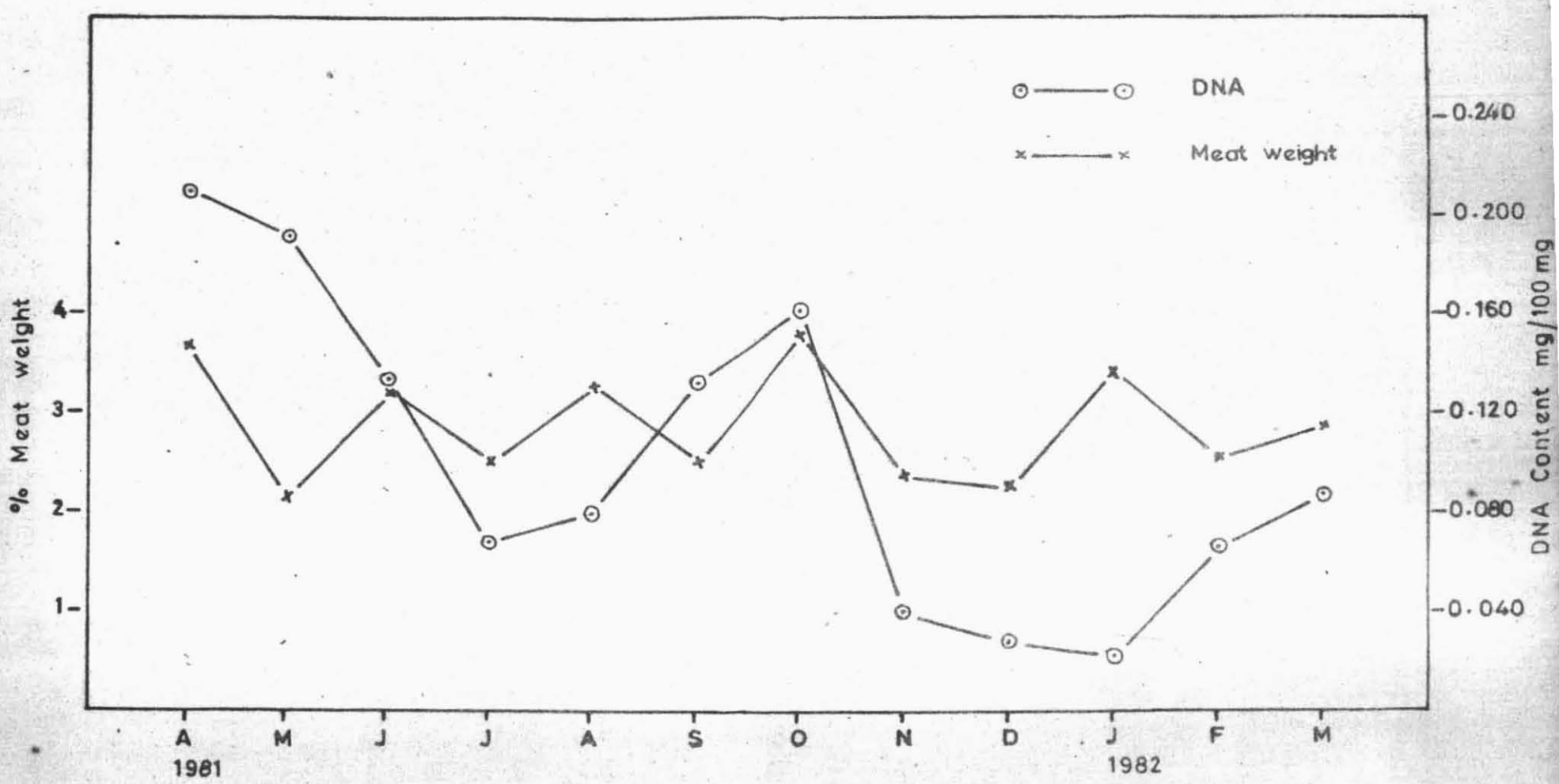


Fig. 29 Monthly variations in the meat weight correlated with the DNA content of the oyster, C. madrasensis.

the increase in the body weight also. When the feeding intensity was high the weight of oysters showed the maximum peak but during this period no corresponding hike in the DNA was observed. Oysters showed that the weight increase due to feeding is not correspondingly accompanied by the DNA increase, but the DNA increase due to maturation was always accompanied by increase body weight also. In the case of RNA, the maximum concentration was observed with the weight increase and also with the high intensity of feeding, but a lower concentration of RNA was associated with maturation of gonad.

DISCUSSION

Though many workers have attempted to study the importance of nucleic acids in the biology of invertebrates, still there lies a large gap in the knowledge of nucleic acids of molluscs. Hinegardner (1974) studied the cellular DNA content of 110 species of molluscs and correlated with their body size and with their chromosome numbers, and found the differences between the generalised and specialised species. He also studied the DNA content of oysters and grouped them under more specialised ones having less DNA content in their body. But he failed to study the DNA content in relation to reproduction, in relation to feeding, the seasonal variations in different body

components, and the relation between the RNA and DNA content of male and female oysters. The fluctuations in the phosphate content in relation to reproduction has been attempted by Durve and Bal (1961), Joshi and Bal (1961), Chari (1966) and Desai et al. (1978).

Oysters of the 101-120 mm size-group were used for the determination of the RNA and DNA contents and based on sampling for one year the ratio of the RNA and DNA contents were observed to be 4 : 5. In all the body components, the DNA content was found to be high. The values of phosphate have shown a similar trend to those of the DNA. The RNA and DNA showed an inverse relationship in the body of oysters during different months and also during the period of reproduction. Whenever the RNA content was high, the DNA content was low and vice-versa, or otherwise the process of maturation of C. madrasensis was characterised by an increase in the concentration of DNA and a corresponding decrease in that of RNA. The application of students 't' -test showed that these changes in the nucleic acid contents were statistically significant ($P < 0.001$).

In practically all organisms there is a positive correlation between the cell-size and amount of DNA in the cell (Hinegardner, 1973). During the gametogenic period, from the I stage to the IV stage, there was a

steady and regular growth in the size of the oocytes, leading to an increase in the weight of the individual cells, an increase in the cytoplasmic volume and a corresponding increase in the DNA per unit weight also. Maturation really causes some increase in the endogenous DNA synthesis even in somatic cells.

During the period of spermatogenesis, there are a series of multiplications of cells from the I stage to the IV stage and thus the number of cells increases, as a result of which the DNA is also increased and thus the weight of the male tissue increases corresponding to the number of cells. This agrees with the views of earlier workers like Hotchkiss (1965), Leslie (1955), Bulow (1970), Jafri and Mustafa (1976) and Mustafa (1977). It is also further illustrated by the sudden fall of DNA immediately after spawning as a result of extrusion of a large number of germ cells.

During the period of regressive stage or cytolysis, there is a possible shrinkage of cells due to reduction in the cytoplasmic volume and consequently there is an increase in the concentration of the nuclei (the store houses of DNA) and hence the DNA per unit weight of the tissue increases. As a result of this the hepatopancreas and gonad have shown a high concentration of DNA and it agrees with similar findings of Love (1958).

Based on the studies of the meat weight of the oysters of the size 101-120 mm in different months, and the variations in DNA contents for those particular months correlations have been studied.

The DNA content of oysters does not show any relationship with their feeding intensity. This is evident by correlating the total DNA content with the feeding intensity and weight increase in the oyster meat. In June '81, there was a higher feeding intensity and correspondingly the meat weight also at its maximum level, but the DNA content was very low. At the time of the fully ripe condition, the feeding intensity was found to be very low, but the DNA concentration was very high in the tissues. In December '81 and January '82 there were higher intensities of feeding, but the DNA was very low. In February '82 feeding was very poor, but the DNA content was found to increase considerably and this might be due to the gametogenesis which was taking place in the oysters. This agrees well with the views of earlier workers (Hawks et al., 1954; Hotchkiss, 1955; Leslie, 1955; West and Todd,1963) who worked on fishes and documented that the quantity of DNA of individual cells does not actually change with the changes in the physiological states like fasting and feeding etc.,.

In fact, cytoplasm is the site for various metabolic substances, and depletion of these substances may occur during maturation, besides affecting the other organic

and inorganic substances of the cells including the RNA. The peak period of high intensity of feeding coincides with the high RNA concentration: and the intensity of low feeding coincides with lower RNA. This agrees with the views of Brachet (1955), Leslie (1955) and Bulow (1970) that there is a decline of RNA during starvation and an increase during feeding.

Gonad of C. madrasensis synthesize large amounts of RNA during the early stages of gametogenesis, and considerable amount of RNA is utilised upto the last stage of maturation. Such a continued synthesis of RNA in the oocytes has also been reported in the echiuroid worm Urechis caupo (Gould, 1969; Millar and Epel, 1973). That the RNA substances are mainly utilised for the endogenous protein synthesis is revealed by the higher quantities of protein from the I stage of oocyte development onwards. A large proportion of RNA synthesized during oogenesis contains gene products to be used to direct protein synthesis after fertilization. At no time during oogenesis there is a large preferential accumulation of either RNA or protein as was observed during the oogenesis of Urechis, as indicated by Millar (1971). During the disintegration of the gamete cells, as a result of cytolysis, the follicle cell nuclei might still synthesize substantial amounts of RNA. In addition, large amounts mitochondria which

accumulate in the ooplasm are a possible source of the continued RNA production (Zolakar, 1976; Capco and Jeffery, 1979).

The higher level of RNA in the gonad, and in the hepatopancreas compared to all the other tissues can be attributed to the greater metabolic activity concerned with physiological changes occurring during reproduction. The gill also showed higher concentration of RNA due to high respiratory metabolic activity. The adductor muscle which is attached to either valves is responsible for the opening and closing of the valves as and when required and no other activity is being undertaken by this in oysters, so that the adductor has a low metabolic activity resulting in low RNA content.

There was no significant variation in the phosphate content of males and females. The phosphate content was at its peak in all the oysters during April and falls to a low level in May due to spawning, as is observed in C. gryphoides by Durve and Bal (1961) and as in Katelysia mormorata described by Joshi and Bal (1961). During high feeding, there was an increase in the quantity of phosphate suggesting that the storage of phosphate in the meat is for a later use.

The adductor muscle has the lowest concentration of phosphates throughout this period of study. The hepatopancreas and gonad have the highest phosphate content compared to all the other body components. The phosphate content increases with the peak period of gametogenesis (July-September). During the post-spawning it decreases again. The decrease in phosphate content during the post-spawning season may be due to the extrusion of enormous numbers of sex products.

During the period of the regressive condition of the gonad, the phosphate content showed a considerable decrease in the mantle, gonad and adductor muscle when compared to the same tissues during the ripe condition of oysters. Among all the tissues there was a considerable hike in the concentration of phosphate in the hepatopancreas indicating the resorption from the gonads.

Earlier studies of Venkataraman and Chari (1951) on the edible oyster C. madrasensis (Preston), Durve and Bal (1961) on C. gryphoides, Joshi and Bal (1961) on Katelysia mormorata and Desai and Nimavat (1978) on the pearl oyster Pinctada fucata have also noted almost similar trends of phosphate fluctuation as explained above in the case of the edible oyster. The fluctuations in the quantity of phosphate content in different seasons reported by Desai and Nimavat (1978) are noted to be very high compared to the present findings on C. madrasensis.

CHAPTER SIX

SEASONAL CHANGES IN THE FOOD VALUE OF THE OYSTER *CRASSOSTREA MADRASENSIS*

The chemical composition and meat weight of the oyster varies according to changes related to environment, season of the year and also the physiological condition of the oyster. Changes in the body weight of the tissue varies greatly according to the changes in water temperature and currents, food supply, exposure to light, intertidal exposure and other factors (Medcof, 1961; Quayle, 1969). Among the environmental parameters, salinity is the main factor affecting the chemical composition of the oyster. The changes in the wet and dry weight of the oyster are mainly influenced by the salinity of the water. Fluctuations in the moisture content due to the absorption of water and loss of solids from the body of animals are the most significant features of changes in the chemical composition of the oyster meat. This sort of changes in the oyster meat during certain periods lowers their commercial value also. A rational and profitable fishing of oyster lies on the basis of obtaining

the highest meat weight with the best biochemical constituents.

In all the body components, the levels of organic constituents and water remain in a pause throughout the year or during some part of the year. The information on the distribution of organic matter in different body components is very scanty. However, few studies have been made on the distribution of organic contents throughout the year (Hatanaka, 1940; Deshmuck, 1972; Nagabhushanam and Mane,1974; Mane and Nagabhushanam, 1975; Stephen, 1980 and Ansell et al.,1980) in bivalve molluscs. Earlier investigations have shown that the water level in the bodies of bivalves tends to increase or decrease with the change in salinity of the sea water (Galtsoff, 1964; Deshmuck, 1972; Ansell et al.1973; Nagabhushanam and Mane, 1974; Mane and Nagabhushanam, 1975 and Miyazaki et al., 1975).

Several methods have been used for assessing the quality of meat. The use of dry weights, glycogen estimation or the total chemical analysis have been widely adopted (Coulson, 1933; Humphry, 1941; Galtsoff,1947; Jacob, 1951; Fieger et al., 1958; Durve, 1976 and Ansell et al., 1980). These methods, though are more precise, yet they can not be employed for large samples due to the time consumed. Estimating the percentage of edibility

and 'index of condition' have been employed by Odlaug(1946), Ingle (1949), Venkataraman and Chari(1951), Korringa (1955), Rao (1956), Durve (1964), Giese et al., (1967), Giese(1969), Sastry (1966a, 1970a), Fuji and Hashizume (1974), Nagabhushanam and Mane (1975) and others. The methods used by these workers being less time consuming, can be effectively adopted for large samples.

The main objectives of the present investigation is to (1) assess the quality and seasonal changes of the meat weight of the oyster (2) find out the seasonal changes in the body component index (3) water level in the different body components, (4) changes in the dry weight of the different tissues of the body (5) changes of flesh weight in relation to reproduction(6) changes of weight in relation to feeding and (7) body weight in relation to biochemical variations.

MATERIAL AND METHODS

After each collection, the oysters were brought to the laboratory. The soft parts of the body after removal from the shell were sorted out into mantle, gill, adductor muscle, gonad and hepatopancreas. All these tissues were separated from each other with utmost care to avoid contamination. The tissues were wiped out to remove the excess of moisture and then weighed. 'The body component

index' of any tissue was determined as the wet weight of the component multiplied by 100 and divided by the wet weight of the entire body. The percentage of edibility of a tissue is the meat weight/total weight x 100.

Each body component was weighed separately in crucibles and then dried in an oven at 80°C to a constant weight. The water content was determined by substracting the dry weight from the wet weight. The percentage of water content was observed for four different size-groups and since there was no significant difference between the water content of different body components at various size-groups, the data was pooled together and is given in the context.

RESULTS

CHANGES IN BODY WEIGHT

The monthly variation in the percentage of edibility or the body weight of the oyster of four different size-groups are illustrated in fig. 30. The monthly variations in the percentage of edibility of males or females follw the same sequence as that of the average edibility of the oysters taken as a whole. Hence the data was pooled together and presented in the Table.26.

The body weight was minimal in May, as soon as they spawn, and was found to increase sharply in all the size-groups during the month of June as a result of high feeding

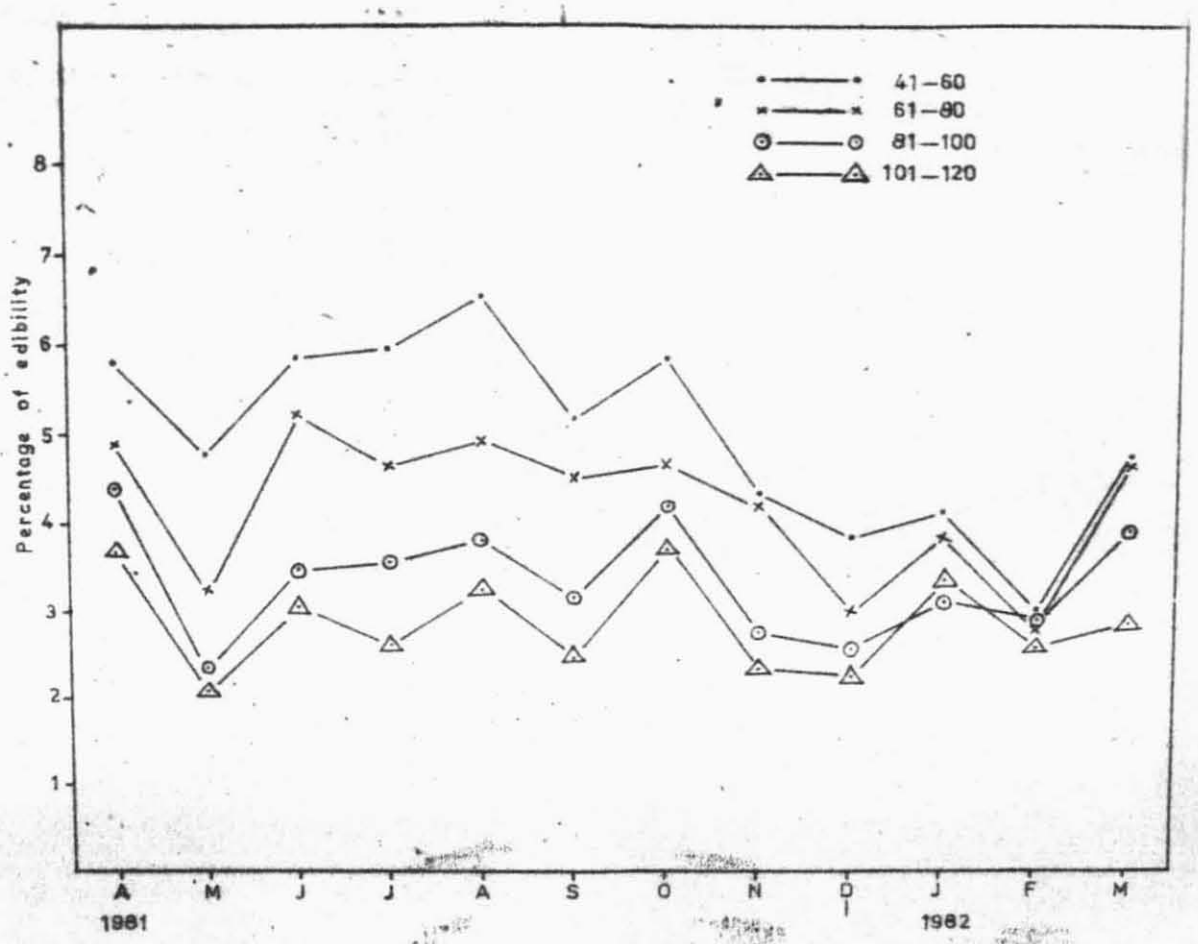


Fig.30 Monthly variations in the average percentage edibility of C. madrasensis during April 1981 — March 1982.

Table. 26.

Monthly variations in the percentage of edibility (Meat weight) of different size group of oyster, C. madrasensis ; each value represents the average estimate of 9 to 36 individuals.

Size of oysters (mm)	Month and Year											
	Apr. 1981	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.1982	Feb.	Mar.
41-60	5.86	4.81	5.90	6.00	6.63	5.24	5.93	4.39	3.92	4.15	3.09	4.79
61-80	4.99	3.23	5.26	4.69	4.96	4.56	4.71	4.33	3.06	3.93	2.88	4.75
81-100	4.40	2.39	3.48	3.52	3.86	3.19	4.25	2.79	2.60	3.15	2.98	3.96
101-120	3.68	2.13	3.19	2.53	3.29	2.50	3.79	2.39	2.30	3.41	2.53	2.88

intensity. The body weight increases slowly with some minor fluctuations reaching its maximum in all the size-groups during the month of August. A very slight reduction in all the size-groups of oysters was observed during the month of September. The reason for the same may be due to poor feeding. In October, all the size-groups of oysters showed increasing trend as a result of ripening of the gonads. Immediately after spawning, the body weight of all the oysters was found to be falling and reaches its lowest level during December. As a result of high feeding the weight increased during January, and fell to a low level in February as a result of low feeding, and increased again till March due to gametogenesis in oysters.

The percentage of edibility varies within the different size-groups. The 41-60 mm size-group has shown the maximum percentage of flesh weight upto 5.11% which is higher than in the other size-groups. The 61-80 mm size-group has shown 4.12% of flesh weight. The higher size-group of oysters, 81-100 mm and 101-120 mm showed 3.46% and 2.97% of flesh respectively. Of all the size-groups, harvesting of 61-80 mm size-group seems to be more profitable in which 4.12% of flesh weight could be obtained. This percentage is certainly higher than for the other two larger size-groups. Although the flesh weight was 5.11% in the 41-60 mm size-groups of oysters, yet it requ-

ires large number of oysters for the required quantity of oyster meat. Therefore, the collection of meat is not quite ideal in the 41-60 mm size-groups of oysters. The maximum weight of all the size-groups was seen during July to August, and in January, as a result of heavy feeding which helps in the accumulation of abundant glycogen and hence fatty oysters are ready for market during this season. The maximum efficiency ratio is said to be reached when the greatest quantity of meat is obtained from an oyster with the lowest total weight or size (Wakamatsu, 1974).

SEASONAL CHANGES IN THE BODY COMPONENT INDICES

The body component profiles of C. madrasensis are given in Fig. 31, from which it is clear that the mantle forms a relatively prominent body component. Gill and labial palps, both constitute the second major body component. Among the other three body components, the digestive gland forms the third major body component and the adductor muscle and gonad are more or less of the same status. Variation in the body component indices during the period of study plotted in fig. 32, which shows that the gonad, hepatopancreas and mantle showed remarkable fluctuations during the different months. In April, the gonad-index seems to be at the peak level due to the ripening of the gonad and it was found to be falling in the subsequent months. But in all other body components, the index

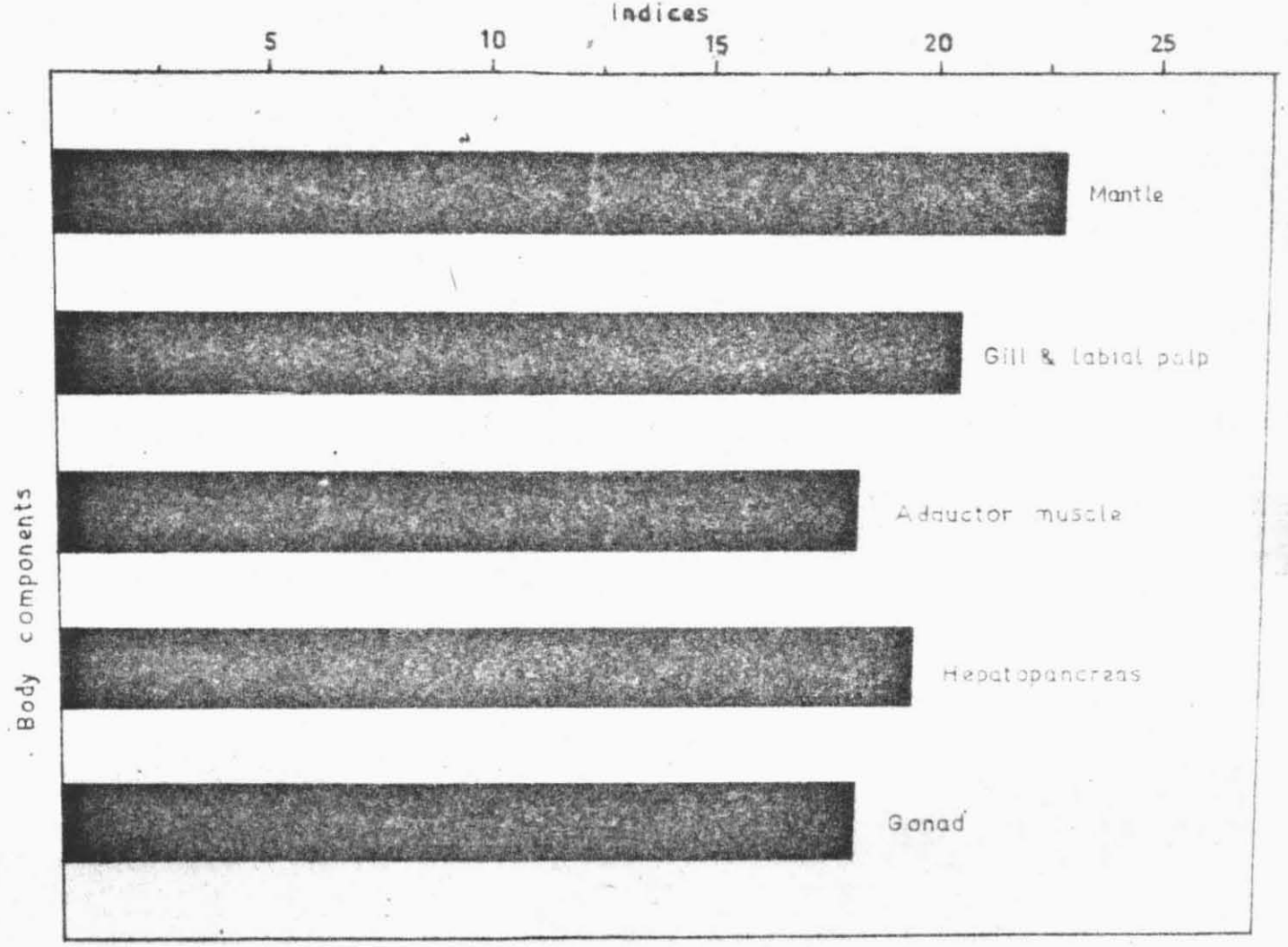


Fig.31 Body component index profiles of Crassostrea madrasensis

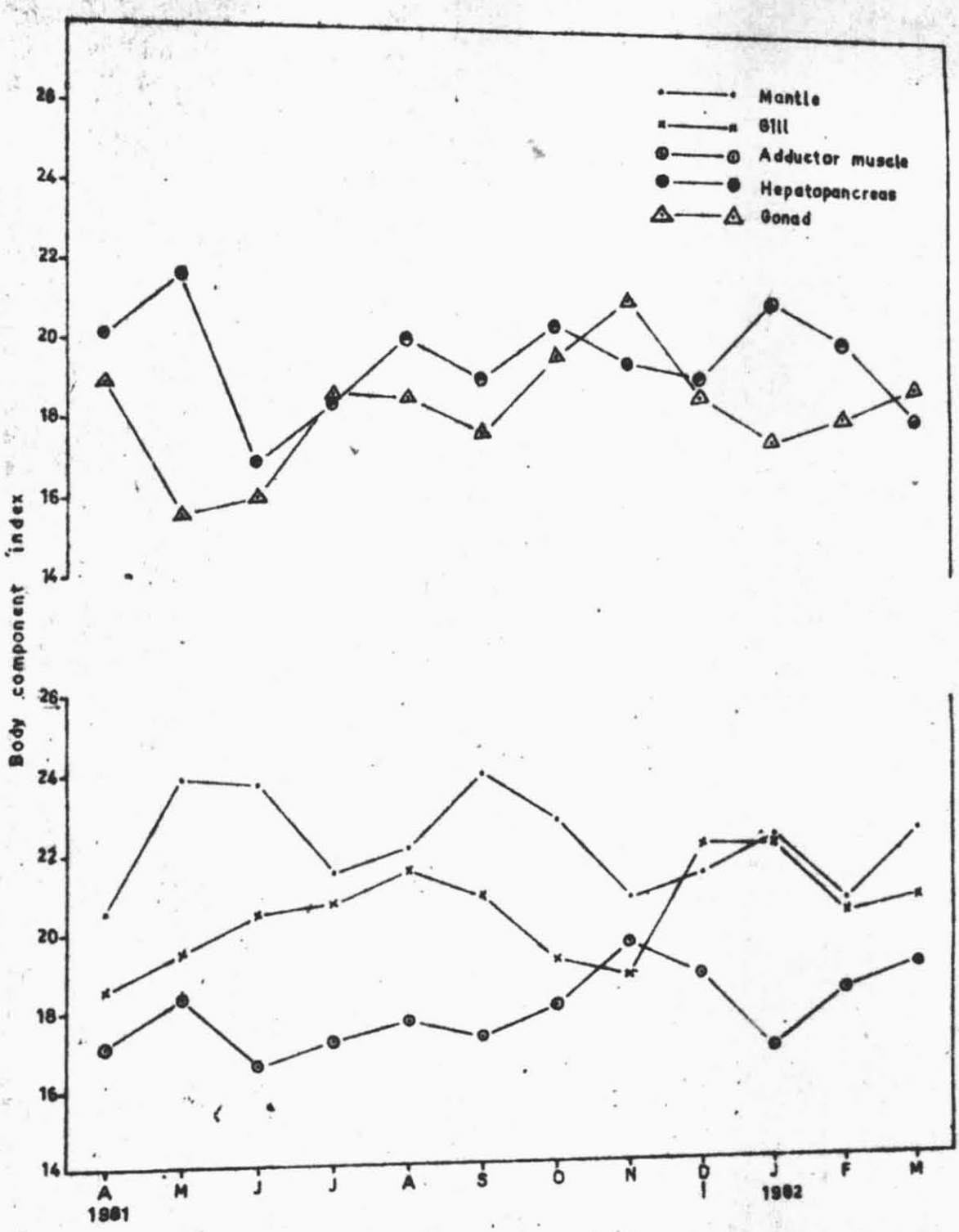


Fig. 32 Changes in the body component indices of *C. madrasensis* during April 1981 — March 1982

Table. 27

Monthly variations in the percentage of wet weight of different body components of the oyster C. madrasensis.

Body component	Month and Year											
	Apr. '81	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec '82	Jan.	Feb.	Mar.
Mantle	20.6 ± 2.33	24.0 ± 5.75	23.8 ± 5.65	21.6 ± 3.52	24.2 ± 2.22	24.1 ± 4.07	22.8 ± 1.58	20.9 ± 2.42	21.5 ± 2.03	22.1 ± 0.99	20.8 ± 2.20	22.5 ± 0.97
Gill	18.5 ± 1.70	19.5 ± 1.74	20.5 ± 3.57	20.8 ± 2.80	21.6 ± 2.18	20.9 ± 4.47	19.3 ± 2.60	18.9 ± 3.20	22.3 ± 2.21	22.4 ± 1.15	20.5 ± 2.86	20.8 ± 1.03
Adductor muscle	17.2 ± 8.12	18.4 ± 1.76	16.6 ± 1.69	17.3 ± 1.79	17.7 ± 2.05	17.3 ± 1.54	18.1 ± 1.20	19.8 ± 1.55	18.8 ± 1.63	16.9 ± 1.29	18.3 ± 2.75	19.0 ± 1.3
Hepato-pancreas	20.1 ± 8.89	21.7 ± 2.92	17.0 ± 2.20	18.4 ± 1.38	20.0 ± 2.12	19.1 ± 3.99	20.4 ± 1.30	19.5 ± 2.21	19.1 ± 1.27	21.0 ± 0.65	20.4 ± 3.82	18.1 ± 3.45
Gonad	19.0 ± 9.45	15.5 ± 3.23	16.0 ± 2.04	18.6 ± 0.69	18.5 ± 1.58	17.7 ± 2.71	19.7 ± 2.37	21.1 ± 4.64	18.6 ± 1.86	17.5 ± 1.28	13.0 ± 1.95	19.0 ± 1.45

values seem to rise gradually and this may be as a result of high feeding intensity. In the month of June, the hepatopancreas index has fallen sharply and the same trend was observed in the adductor muscle and mantle, and its decline was very feeble. Gonad and gill alone showed a slight increase in the value of their indices. During the months of July and August, the indices of all the body components except the gonad showed an increasing trend. The gonad index was found to decline and the hepatopancreas was found to rise gradually. From September to November the gonad-index seems to rise sharply and the digestive gland-index was found to decline considerably, especially in November. This is mainly due to the ripening of gametes, and the decline in the digestive gland may be due to the transfer of nutrients from the hepatopancreas to the gonad. The digestive gland-index was higher than the gonad-index during May and early June. The digestive gland decrease to a value less then the gonad-index by July and thus a reciprocal relationship was maintained until the end of the reproductive period and it again decreases to the lowest level when the oysters were ripe and again showed an increasing trend in the digestive gland-index during later part of November, immediately after spawning. Thus a decline in digestive gland-index occurs during the period of gonad growth, as a result of rapid transfer of nutrients from the ingested food. The digestive gland-index is higher

than the gonad-index during the vegetative phase and during the resting stages in the reproductive cycle of the oysters. The weight of the mantle and gill also showed the same trend as in the case of the hepatopancreas and gonad. The adductor muscle was found to increase in the index value during November and the reason for the same may be due to a rise in the carbohydrate content in this tissue. As a result of spawning, at the onset of the North East monsoon, the index of gonad was brought down during November and the same trend was continued till January 1982. The index of mantle, gill and hepatopancreas showed an increasing trend during this period and this may be the result of high feeding. The index of gonad, gill and mantle showed an increasing trend during the period between January and March. The index of hepatopancreas showed a decreasing trend during this period perhaps due to the transfer of nutritive material from the hepatopancreas to the gonad. The index of gonad and hepatopancreas showed an inverse relationship during the entire period of this study.

WATER LEVELS

The water content of the entire body during the period of study revealed that the percentage of water was at the maximum level, giving an average of 82.54%

during December and the minimum level of 72.08% during the month of May, coinciding with the monsoon period and summer months respectively (Fig. 33 & Table 28). The water content during the rest of the period showed no significant vatiations. It is interesting to note that the moisture content of Crassostrea madrasensis remains relatively constant throughout the year for all the body components. The percentage of water content in all the body components is given in fig. 32. The water level (79.8%) was found to be highest in the gills than in the other body components. The water content in the mantle also was high, but slightly lower than in the gill (79.16%). The adductor muscle has shown an intermediate status in its water content (77.05%). The lowest level of water content was observed to be the average level of 76.41% and 75.79% in the digestive gland and gonad respectively.

The water content in the different body components of the oysters varies considerably from season to season. Both the gonad and the hepatopancreas showed the lowest level of water content during the first week of May and September, as a result of ripening of the gonad. This water content has been found to reach maximum level during the month of June and October-November, immediately after spawning. The same trend has been observed in all the other body components also. The percentage of water

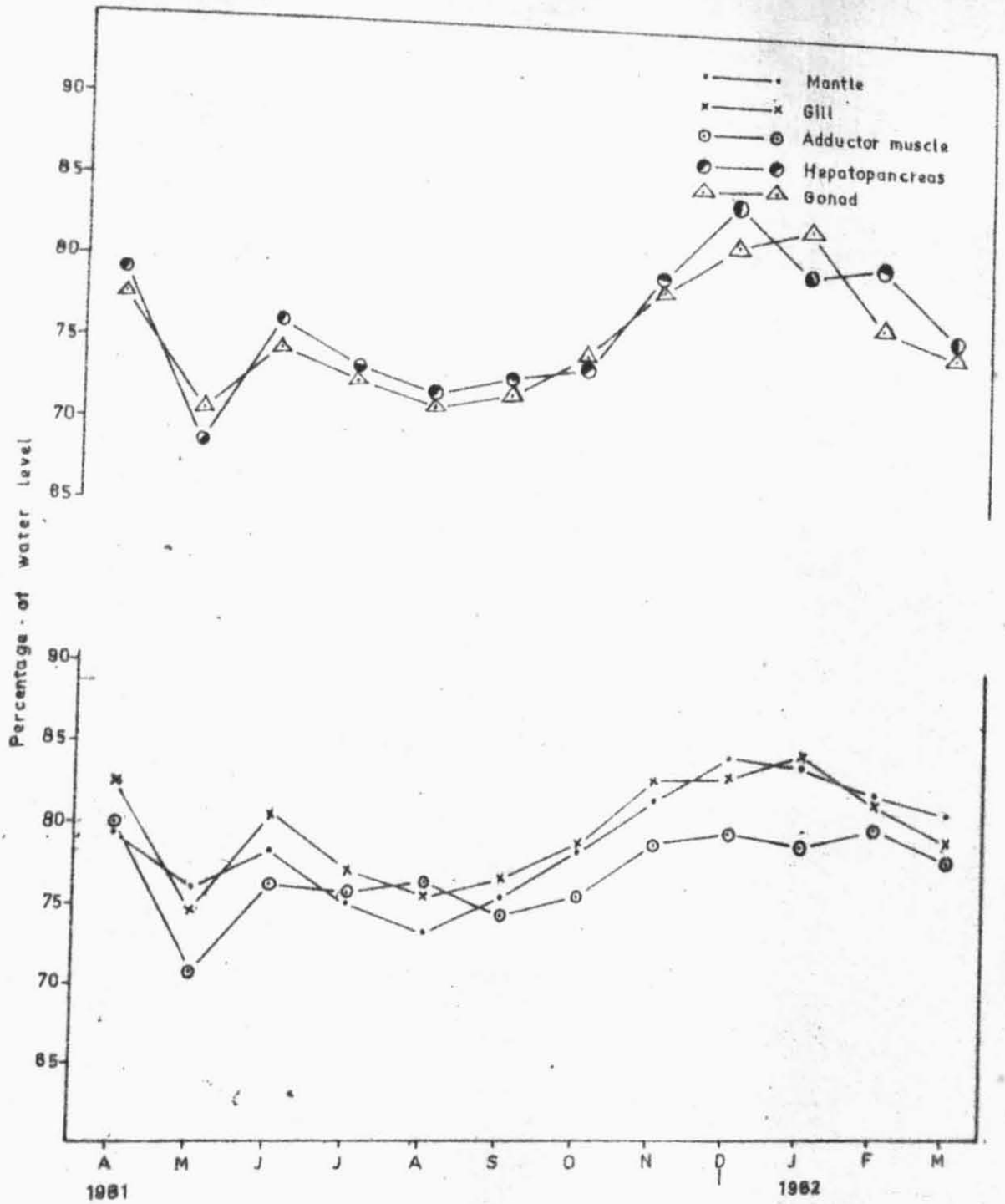


Fig.33 Percentage of water level in the mantle, gill, adductor muscle, hepatopancreas and gonad of C. madrasensis.

Table. 28

Percentage of water level observed in different body components of the oyster C. madrasensis.

Body component	Month and Year											
	Apr. '81	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.'	Jan.'82	Feb.	Mar.
Mantle	79.01	75.23	78.93	75.05	73.55	75.70	78.43	81.75	84.45	84.36	82.31	81.13
Gill	82.60	74.96	80.62	77.11	75.64	76.93	78.61	82.77	83.01	84.60	81.44	79.27
Adductor Muscle	79.78	70.67	76.28	75.85	76.19	74.64	75.64	78.92	79.72	78.96	80.04	77.86
Hepatopancreas	79.13	68.73	76.23	73.30	72.22	73.13	73.38	78.47	84.04	80.14	80.85	76.33
Gonad	77.84	70.82	74.73	72.98	71.75	72.40	74.00	78.94	81.47	80.92	76.31	75.1

content of gonad was found to be slightly lesser than in the hepatopancreas at the time of maturation of gametes, but soon after spawning, the gonad and hepatopancreas showed reciprocal relationship in the level of the water content. The mantle which was found to be low in its water content during the ripe condition of the gonad showed a hike soon after spawning during the monsoon period and this may be attributed due to the loss of salts into the less saline waters in the lake. The water content in all the body components was found to decline slowly from June to September during which period the gametogenesis was taking place in the oysters and correspondingly the salinity was also found to be high. The water content started to rise in all the body components from the month of September corresponding to the decline in the salinity of the lake waters. The lowest salinity in the lake was observed till January and this was reflected in the tissues showing the highest percentage of water content. This suggests that the seasonal changes in the water content of the oysters are related to the changes in salinity of the estuarine waters.

CHANGES IN DRY WEIGHT OF THE DIFFERENT BODY COMPONENTS

The monthly variation in the tissue weight of the the different body components of the oysters are illustrated in fig. 34 & Table 29. The dry weight of the mantle

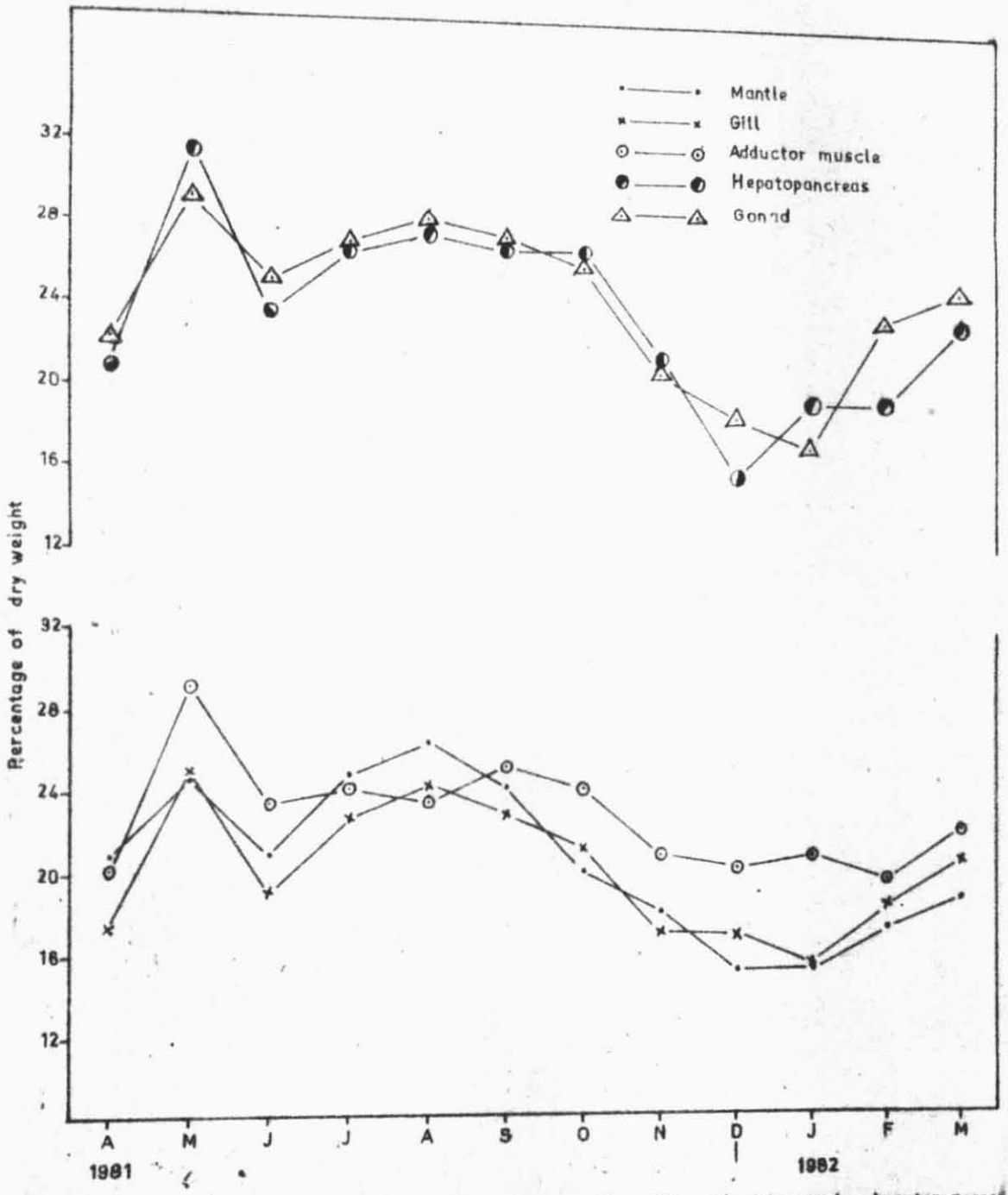


Fig.34 Percentage of dry weight of the mantle, gill, adductor muscle, hepatopancreas and gonad of *C. madrasensis*, during April 1981 — March 1982.

Table. 29

Monthly variations in the percentage of dry weight of the different body components of C. madrasensis

Body part	Month and Year											
	Apr. '81	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan. '82	Feb.	Mar.
Mantle	20.0 ± 2.47	24.8 ± 4.11	21.1 ± 2.97	24.1 ± 1.05	26.5 ± 0.78	24.3 ± 1.98	21.6 ± 3.27	18.2 ± 1.67	15.6 ± 2.21	15.6 ± 0.91	17.9 ± 2.73	18.8 ± 2.41
Gill	17.4 ± 7.58	25.0 ± 3.76	19.4 ± 2.90	22.9 ± 0.92	24.4 ± 1.93	23.1 ± 1.51	21.4 ± 4.09	17.2 ± 2.55	17.0 ± 3.81	15.4 ± 1.56	18.6 ± 5.18	20.8 ± 1.25
Adductor muscle	20.2 ± 3.44	29.3 ± 2.00	23.7 ± 2.78	24.2 ± 1.74	23.8 ± 1.15	25.4 ± 2.24	24.4 ± 4.31	21.1 ± 4.22	20.3 ± 2.85	21.0 ± 3.31	20.0 ± 3.63	22.1 ± 0.99
Hepato-pancreas	20.9 ± 2.99	31.3 ± 2.80	23.8 ± 2.52	26.7 ± 1.71	27.8 ± 2.63	26.9 ± 2.04	26.6 ± 4.29	21.5 ± 3.72	16.0 ± 2.92	19.9 ± 1.96	19.2 ± 4.77	23.7 ± 4.17
Gonad	22.2 ± 3.93	29.2 ± 4.72	25.3 ± 2.72	27.0 ± 0.91	28.3 ± 1.84	28.6 ± 1.40	28.9 ± 2.78	21.1 ± 3.29	18.5 ± 3.54	17.2 ± 3.89	23.4 ± 5.07	24.9 ± 3.06

varied between 15.55% to 26.45%. The maximum dry weight of the mantle corresponds to the accumulation of glycogen or fat during August, and hence the low value was the result of elimination of all stored materials during the month of December for spawning. The dry weight of the gill was ranging between 15.4% and 25.04%. The lowest level was found in January and the highest value during May, when the gonad was in the ripe condition. The adductor muscle has shown the highest weight (29.33%) during May and the lowest weight during February (19.96%). The maximum weight in the hepatopancreas (32.17%) and the gonadal weight (29.18%) observed during the first week of May was the result of the ripening of gametes and also due to the rise in the salinity of the lake. The fall in the dry weight of the hepatopancreas (15.95%) and gonad (17.18%) during December and January may be due to spawning and also due to changes in the salinity of the lake waters.

CHANGES OF BODY WEIGHT IN RELATION TO REPRODUCTION

Seasonal changes in the body weight in relation to the gametogenic activity are also observed in C. madrasensis. The body weight of the oyster is minimal in May and February and increases gradually towards the onset of gametogenesis. The process of proliferation of gametes takes place from July-October, and from February-April. Correspondingly, the weight of the oysters also was found to

increase gradually till the ripening of gametes. Body weight begins to decline during May and November, and the sex of the animals could not be distinguished properly, as a result of spawning and as a result of the limited food supply, and the utilization of the stored food. The overall decrease in the body weight during the month of February represents the net deficity of food available in the environment to meet the metabolic requirements of the animal.

CHANGES OF BODY WEIGHT IN RELATION TO FEEDING

The flesh weight of the oyster varies during the different months of the year depending upon the intake of food, reproductive activity, changes in the metabolic activity of the animal. Nutrients from the ingested food may be stored in the digestive gland and distributed to the other important organs when the gonads are in the resting stage.

In some bivalves, the gonad growth and gametogenesis are dependent upon the direct intake of food during the period of gonad development. Maximum feeding intensity was observed during June and as a result, the weight of the body was found to rise sharply due to the accumulation and storage of glycogen. The energy stored in the form of glycogen was accompanied by weight increase and it was found to maintain more or less the same weight in the

subsequent months also, but feeding intensity was found to decline very sharply during the month of October due to the active proliferation of gametes by utilizing the stored glycogen from the hepatopancreas. The weight of the oysters dropped considerably during November and December immediately after spawning, but the feeding intensity was found to increase very rapidly after December. The weight of all the size-groups was found to be minimal during the month of February indicating the very low intensity of feeding during this period. The weight of the hepatopancreas and mantle were found to increase considerably during the month of May and June due to the accumulation of reserve materials when the feeding intensity was very high. The gonad weight was found to increase only during the period of gametogenesis by the mobilization of reserve food from the hepatopancreas and mantle, hence the gonad does not show any relation between the feeding intensity and the weight increase directly. However, when the feeding intensity is poor it reflects on the gonad through the storage organ thereby reducing the storage materials. Gonad growth and gametogenesis are dependent upon direct intake of food in most of the bivalves. However, in the oyster, the gonad received the nutrient supply from the hepatopancreas and mantle where it was stored when the feeding intensity was high. Thus the gonad of the oyster during the period of active gametogenesis, accumulates or utilises nutrients at the expense of the other organs.

BODY WEIGHT IN RELATION TO BIOCHEMICAL VARIATIONS

Biochemical constituents of the oyster varies with the feeding, reproductive activity, physiological conditions, salinity, temperature, and also due to external stresses like starvation and desiccation. In this context, the biochemical constituents such as protein, fat, carbohydrate, nucleic acids and inorganic phosphate of the body components were correlated with the chnages in the flesh weight of the oysters. During the month of May and November, the protein, fat, inorganic phosphate and DNA were found to decrease considerably due to the extrusion of large number of gametes, resulting in the loss of weight of the oyster, but the glycogen and RNA constituents are on the upward trend. During the month of June-July, glycogen and RNA were found to rise to the maximum level due to the high intensity of feeding and thereby the weight of the oyster increases considerably during this period. There was an increase in the weight, and correspondingly the protein, fat, DNA and phosphorus also were found to increase during the period of gametogenesis (August-October), and associated decrease in the glycogen and RNA due to utilization of this energy in the formation of proteins and fats. Most of the oysters in the resting stage during February were found to contain RNA and glycogen but at a moderate level since during this period, feeding intensity was very low. The maximum weight of the oyster was observed from June to October with the highest fluctuations during August and October indicating that they are

rich in glycogen in the preceding months. Protein, fat and DNA contents gradually increase in the later months reaching their peak levels during October when the oysters reach the ripe condition. Hence the oysters, rich in glycogen and rich in protein may be obtained by harvesting them during the months of August and October respectively.

DISCUSSION

Changes in the body weight, body component index, percentage of water in the body, in relation to feeding in bivalves have been studied by various investigators (Daniel, 1922; Pease, 1932; Venkataraman and Chari, 1951; Hori, 1954; Fraga, 1956; Fuji, 1957; Durve and Bal, 1961; Tucker, 1961; Giese and Araki, 1962; Durve, 1964; Galtsoff, 1964; Joshi and Bal, 1965; Trevallion, 1965; Lawrence et al., 1965; Sastry, 1966a, 1970a; Giese et al., 1967; Blackmore, 1969; Giese, 1969; Saraswathy and Nair, 1969; Kirby-Smith, 1970; Ansell, 1964a, 1972, 1974, 1974a; Deshmuck, 1972; Nagabhushanam and Mane, 1973, 1975; Comely, 1974; Mane and Nagabhushanam, 1975; Nagabhushanam and Dhamne, 1977; Nagabhushanam and Bidakar, 1978; Ansell et al., 1973, 1980 and 1981).

Seasonal changes in the body weight and changes in relation to reproduction of C. madrasensis are studied for a period of one year. There was a gradual increase in

the body weight during the period of gametogenesis from July to October and subsequently a fall in the body weight immediately after spawning. The body weight is minimal in May and November soon after they spawn. Again the body weight was observed to increase during the month of June and January as a result of utilization of food from the surrounding waters and the consequent building building up of reserves in the subsequent months. The changes in this species agree with the views of Ansell and Tevallion(1967) .eported for Tellina tenuis and of Ansell et al., (1980)for Donax trunculus L. Based on the meat-weight ratio in the different size-groups of oysters, it is recommended that commercial harvesting of the 61-80 mm size-group may be more profitable than the other size-groups. Beyong this size-group, only the shell weight increases. Glycogen-rich oyster meat is obtainable during the months of July and February, but protein -rich oyster meat can be obtained during the month of October and April.

Changes in the body component index have been studied to see whether they vary in relation to the reproductive cycle and in terms of nutrient supply from the storage organ to the organ of demand during the period of gametogenesis. A histogram of body components shows that the mantle and gill form prominant body components of which the former showed more fluctuations than the latter.

Other body components such as hepatopancreas and gonad have the second place but showing remarkable fluctuations during the period of study. The index of adductor muscle was found to be very low compared to the other body components. There was a reciprocal relationship between the gonad-index and the digestive gland-index wherein the gonad-index increases as the reproductive phase approaches but declines after spawning. The digestive gland-index was found to rise as a result of accumulation of energy-rich nutrients during high feeding and declines very slowly with the onset of gametogenesis, as a result of transfer of nutrients to the gonad. The same pattern of fluctuation in the gonad-index during the reproductive season was observed by Giese et al. (1959); Giese and Araki, (1962); Giese and Hart (1967) in Katherina; Tucker and Giese (1962), Lawrence et al. (1965) in Cryptochiton; Giese et al. (1967) in Tivela stultorum; Sastry (1966, 1970a) in Argopecten irradians; Deshmuck (1972) in Meretrix meretrix; Nair and Shynamma (1975) in Villorita cyprinoides.

There is a relationship between the salinity and the biochemical composition of the oyster either directly or indirectly associated with the changes in the physiological status of animals and also with the nutritional conditions, as observed by Durve and Bal (1961), Saraswathy and Nair(1969) and Venkataraman and Chari (1951). The less saline condition

reduced the gametogenic activity of C. virginica(Butler,1949) because it indirectly affects the availability of food and feeding intensity. The variation in the water content of the body of molluscs depends upon the changes in the salinity of the estuary.

Lamellibranchs usually contain the greatest amount of water in their body. The reported water content in Donax hanleyana is 61.03% while in Donax cuneatus it is 70.26%, Ostrea edulis (78.7% to 87.36%), Crassostrea virginica, and C. gigas (80.38% to 82.55%), Mytilus edulis (75.74% to 82.70%), Pecten irradians (80.32%), Mya arenaria(83.46%) Venus mercenaria (84.56%), Cardium edule (92%) and in Martesia fragilis (77%). However, in the oysters of Pulicat, the range of water content was found to vary between 72.08% to 82.54%.

Unlike the mantle (Stephen, 1980), the gill was maintained at a slightly higher level of water content during this period of study, agreeing with Giese (1966), and Mane and Nagabhushanam (1975). The lowest level of water content was observed in the gonad. Many workers reported the effect of salinity on the water content of marine bivalves (Joshi and Bal, 1965; Pease, 1932 and Nagabhushanam and Mane, 1973). Water content was found to increase in the body of the oyster during the monsoon season as a result of heavy influx of

of freshwater into the lake. Under such circumstances there is a probable chance for the loss of salt from the body and thereby a corresponding gain of water by the oyster. Thus there was a reciprocal relationship between the water content of the body and the biochemical or chemical constituents in the body of the oyster. This agree with the findings of Daniel (1922), Fraga (1956) in Mytilus edulis; Hori (1954) in Corbicula sandai, Fuji(1957) in Corbicula japonicum, Durve and Bal (1961) in Crassostrea gryphoides; Galtsoff (1964) in C. virginica; Nagabhushanam and Mane(1974) in Katelysia opima; Nagabhushanam and Talikhedkar (1977) in Donax cuneatus. Maximum percentage of the water content coincided with minimum flesh weight of the oyster, and accordingly the water content was high during the monsoon season.

The water content was found to be low in the gonad during the period of gametogenesis, and soon after spawning there exists a reciprocal relationship in the water content in both the hepatopancreas as well as in the gonad. The mantle which was low in its water content during the fully ripe stage showed a hike in the water content after spawning, may be due to the loss of salts and gain of water during the monsoon season. There was a reciprocal relation in the water content between the gill and the mantle.

The study of the monthly variations in the dry weight of all the body components reveals that the gill and the mantle showed the lowest percentage of tissue during most of the months. The adductor muscle was found to be in the intermediate level in the dry weight. The hepatopancreas showed the maximum level immediately after spawning and also as a result of heavy feeding. The dry weight of the gonad was maximum at the time of gametogenesis and falls to the lowest level during the period of spawning. This agrees with the views of Ansel et al., (1973) in Donax spiculum.

The body weight of the oyster increases during the period of gametogenesis and was found to decline immediately after spawning. The relationship between food and gonad development has been studied in detail for only a few species (Sastry, 1966, 1968, 1970a and 1975; Sastry and Blake,1971; Gimazane, 1972; Bayne, 1975, 1976a). For many species it is not clear whether the gonad development is depending upon the food ingested directly from the surrounding water or upon the reserve food, Gonad growth and gametogenesis are dependent directly upon the intake of food during the period of gonad development in Argopecten irradians (Sastry, 1966, 1968, 1970a); Tellina tenuis (Trevallion, 1971), Abra alba and Chlamys septemradiata (Ansell, 1974a,b); Placopecten magellanicus (Thompson, 1977; Ehinger, 1978); Mercenaria mercenaria (Loosanoff, 1937b) and Venus striata(Ansell,1961b).

In certain other bivalves seasonal gonad development is linked with the storage and utilization of reserves accumulated in the body during the period of phytoplankton bloom (Ockelmann, 1958). According to Loosanoff (1965) the quantity of gametes produced in C. virginica is dependent on the amount of food ingested and on the reserves accumulated during the preceding recovery period. The inter-relationship between food and reserves, energy metabolism and gametogenic activity in Mytilus edulis have been studied in detail and also have been estensively reviewed by Bayne(1976, 1976b) and Gabbott (1975, 76).

In most of the bivalves nutrients accumulated during the period of high intensity of feeding, especially in summer, are utilised for gametogenesis during the following autumn and winter (Chipperfield, 1953 in Mytilus edulis Comely, 1974 in Pecten maximum; Lemmens, 1967 and De Wilde, 1975 in Macoma balthica). The oyster, C. madrasensis in Pulicat agrees with the above findings in reserving the food in its hepatopancreas and mantle, when the food is abundant in the environment and later the reserved food is used for gonad development. Body weight and the gonad-index increase simultaneously form July to October during the period of gametogenesis. The index of gonad and hepatopancreas showed inverse relationship during the entire period of study. The increase in body weight immediately after

spawning represents an accumulation of nutrient reserves in the tissues of C. madrasensis.

Seasonal changes in the flesh weight and biochemical composition are some of the characteristic seasonal activities of bivalves which result from storage and utilization of food reserves (Ansell, 1972; Dare and Edward, 1975). In C. madrasensis during the month of May and November the flesh weight declines along with the biochemical constituents such as protein, fat, phosphorus and DNA, due to the extrusion of a large number of gametes. The weight increase was observed during the month of June-July accompanied by the increase in the carbohydrate and RNA, due to high intensity of feeding.

CHAPTER SEVEN

HOST-PARASITE RELATIONS BETWEEN *BUCEPHALOPSIS HAEMEANA* (LACAZE-DUTHIERS) AND *CRASSOSTREA MADRASENSIS* (PRESTON) ON THE PULICAT LAKE.

There are several instances of mass mortalities of oysters in the Japanese literature dating back to 1915. Takeuchi et al. (1960) reviewed the literature on the large scale mortality of oysters at the Kanasawa Bay, beginning from 1915 and continuing for a number of years. Fujita et al. (1953) reported similar mortalities in Miura peninsula and on the Hiroshima Bay and the adjacent localities (Ogasware et al., 1962). Sindermann (1966) observed significant levels of morality of oysters in the Mitsushima Bay oysters, suspended from the rafts. A 10 year study (Takeuchi, 1963; Takeuchi et al., 1955, 56,57 & 60) provided somewhat inconclusive evidence that the pathogen responsible for the mass mortality was bacteria. Hirsch (1921), Dollfus(1923) and Korringa (1947) reported mass mortalities of mussels, probably due to a contagious disease during the period 1900-1919. A mortality with characteristics very similar to those seen in Ostrea edulis was

described by Roughley (1926) in a population of rock oyster, Crassostrea commercialis from Australia. Howell (1967) observed that the decline in the abundance of oysters in the New Zealand beds was largely due to thehigh prevalence of the trematode infection by Bucephalus longicornutus. During laboratory breeding experiments, Miller (1963) studied the mortality of Ostrea edulis imported from New Zealand. This was attributed mainly to the infection by larval trematodes. Massive invasion of the American oyster-beds in the Southern Texas by metacercariae was reported by Little et al. (1966). Sindermann and Rosenfield (1967) found the Pacific oysters from Taiwan to be infected with larval Bucephalus. Hyper-parasitization of the sporocysts of Bucephalus in the American oysters from the Gulf of Mexico was reported by Mackin and Loesch (1955). Tang and Tang (1976) studied the life cycles of both Parabucephalopsis prosthorchis and Dollfustrema foochowensis. Limnoperna lacustris (v. Marten's) serves as the intermediate hosts for both of them and the vertebrate hosts are fish such as Carassius auratus and Clarias fusus. Tang and Zhezzu (1980) have reported a digenetic trematode Asymphlodora stemthyrae which grows to maturity within a single molluscan host and he also mentioned that altogether 34 species of progenetic trematodes were recorded either from molluscs, crustaceans or insects. The 'Black root' disease of the razor clam in the estuary of Juilong River, at Fujian was described by Tang Chungti (1980). Tang and Tang (1980)

studied the life histories of two species of Aspidogastrids for which the molluscan host is Corbicula fluminea Nuller, and the vertebrate host is Amyda tuberculata (Cantor), and for the Aspidogaster indica the primary host is Limnoperna lacustris (Martens) and their vertebrate hosts are two species of freshwater fishes.

According to Cheng (1967) there are only a few fairly well recognised super families of Digenetic Trematodes, but the taxonomic groups have the familial level are still being debated. The British and the continental European trematodes have been adequately monographed by Dawes (1947), and more recently by Yamaguti (1958) who has done an extensive taxonomic study of all the known digenetic trematode of oysters. Schell (1970) has provided an identification manual to the more common species in North America, north of Mexico. In addition LaRue (1957) has suggested a taxonomic scheme for the higher categories. Samuel (1976) pursued a morphological study of this parasite and placed it under the order Digenea, sub-order Gasterostome, Family Bucephalidae, and Genus and species Bucephalopsis haimeanus. In the oysters, Crassostrea madrasensis, their extent of infection, effect on the host and the preventive measures are investigated on the Pulicat Lake for 24 months.

MATERIAL AND METHODS

Fortnightly samples of oysters from the Pulicat lake oyster-beds were collected. After taking the linear measurements, they were shucked properly and the gonad was examined under the microscope by taking a portion of the gonad for a smear in the live condition. Every month, the total number of oysters infected by the trematodes were noted. A total of 2812 oysters have been examined during the period between December 1980 to March 1982.

HOST PREFERENCE

SIZE OF OYSTERS INFECTED

Almost all sizes of oysters were found infected except the spat, but the extent of infection may vary in different size-groups (Fig.35). Oysters ranging from 50-59 mm size to 100-109 mm size were found to be more infected than the smaller ones, below the size of 50 mm. This is mainly due to their smaller size of the gonad in the oysters below 50 mm size. Highest percentage of infection upto 15.76%, was found in the oysters of size 60-69 mm, and the same was found in the 100-109 mm size group of oysters also(Table 30). The percentage of infection was also less in the oysters of the size-group above 110 mm. Oyster spat below the size range of 10-19 mm were also examined, but these young oysters were totally devoid of any parasitic infection and in some of them the gonad

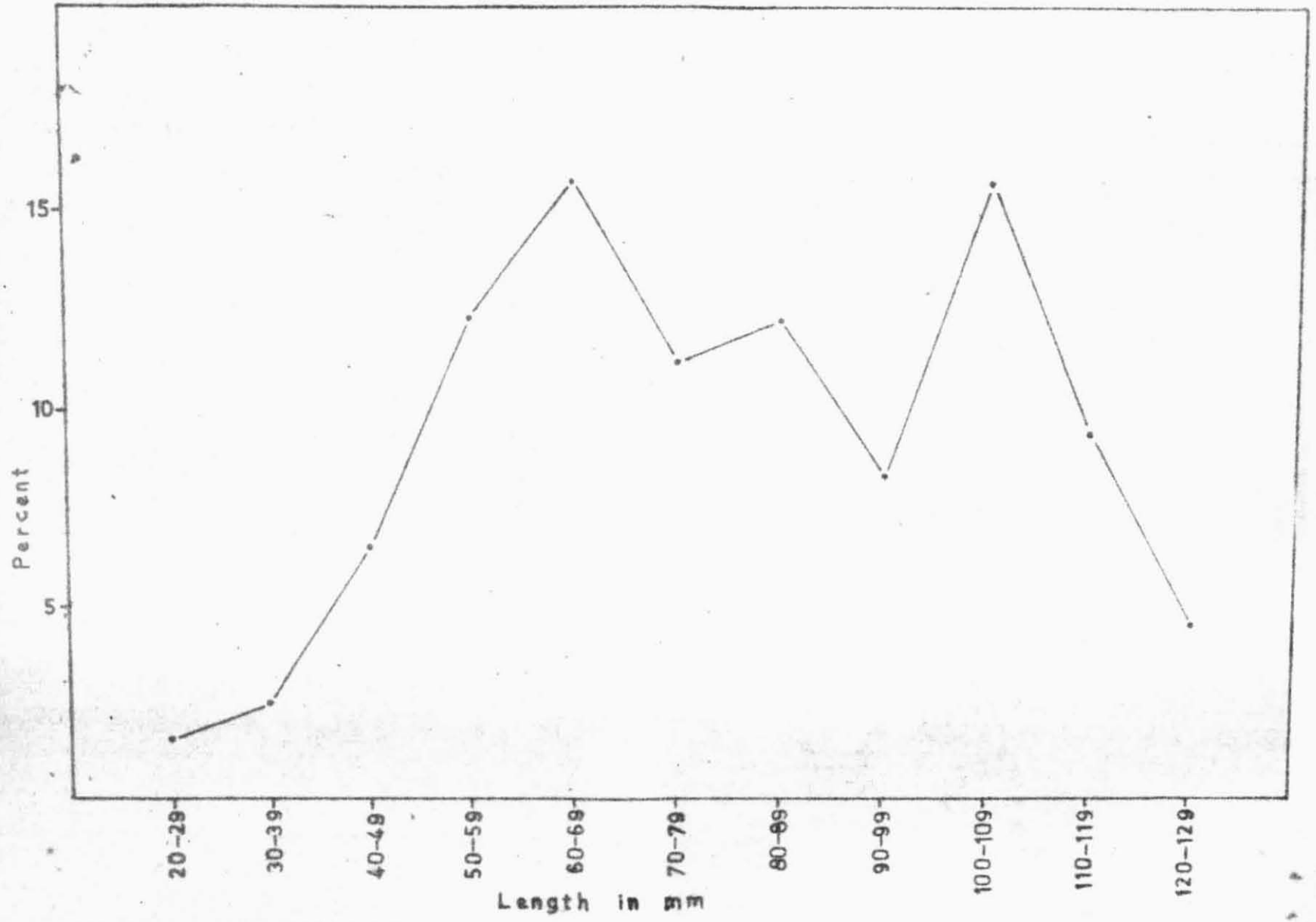


Fig. 35 Extent of infection of Bucephalus haemeanas on the different size groups of the oyster, C. madrasensis.

Table. 30

Seasonal variations in the infection of oysters by Bucephalus haemeana for the from Dec 1980 - February 1982

Size (mm)	Month and Year																Total	Percentage
	Dec'80	Jan'81	Feb	Mar	Apr	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan '82	Feb	Mar.		
20-29	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1.48
30-39	-	1	1	-	-	-	-	-	-	-	-	1	1	-	1	-	5	2.46
40-49	2	3	2	-	-	-	-	-	-	-	-	1	1	4	-	-	13	6.40
50-59	-	6	1	2	-	-	1	-	-	-	-	6	6	2	-	1	25	12.32
60-69	2	3	2	1	-	-	-	-	-	-	-	7	9	6	1	1	32	15.76
70-79	1	2	3	3	-	-	2	-	-	-	-	1	5	5	1	-	23	11.33
80-89	1	2	3	4	-	-	-	1	-	-	-	2	5	3	3	1	25	12.32
90-99	2	5	5	3	-	-	-	-	-	-	-	1	-	-	-	1	17	8.37
100-109	4	3	6	5	-	-	-	-	-	-	-	1	5	3	5	-	32	15.76
110-119	2	3	4	1	-	-	2	-	-	-	-	1	3	1	-	2	19	9.36
120-129	-	3	3	1	-	-	-	-	-	-	-	-	1	-	-	1	9	4.43
Total	14	34	30	20	-	-	5	1	-	-	-	21	36	24	11	7	203	
Percentage	6.90	16.75	14.78	9.85	-	-	2.46	0.49	-	-	-	10.34	17.73	11.82	5.42	3.45	—	100.00

could not even be traced properly.

MATURITY OF GONAD

FEMALES : The gonadal stages of the oysters during the period of parasitism is given in Table.31. The onset of parasitism was found during the ripe condition of the gonad. Majority of oysters were found in the spent condition with a few ova to represent the sex of oysters and the percentage of spent ones was 81.82, 70.83, 76.92 and 35.7 for the months of December '80, January, February and March 1981 respectively. Among the infected individuals, the percentage of ripe females was very low. Only five oysters were found infected during June and all the other oysters were found in the spent condition. Percentage of partly spent oysters was found to be more or less equal to the infected ripe oysters for the period from December '80 to March '81. In the subsequent year i.e., from November '81 to March'81, most of the oysters were in the spent condition whereas the ripe or partly spent ones were negligible. During December'81 and February '82, 100%of the infected females were in the spent condition. In March, 82, 50%oysters were in the ripe condition and 50%in the spent condition.

MALES : In the case of male oysters also, the percentage of the spent ones seems to be higher than the ripe or partly spent ones throughout the period of study except for the months of November '81 and March '82. In ripe males

Table. 31

Showing the gonad condition of infected oysters.

Sex & Stage	Dec'80	Jan'81	Feb	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.'82	Feb.	Mar
Females																
Ripe	9.09 (1)	12.50 (3)	11.54 (3)	21.43 (3)	-	-	-	100 (1)	-	-	-	14.29 (2)	-	10.00 (1)		
Spent	81.82 (9)	70.83 (17)	76.92 (20)	35.71 (5)	-	-	100 (5)	-	-	-	-	85.71 (12)	100.00 (22)	60.00 (5)	100.00 (5)	50.00 (2)
F.spent	9.09	16.67	11.54	42.86	-	-	-	-	-	-	-	-	-	30.00	-	-
Males																
Ripe	-	22.22 (2)	50.00 (1)	16.67 (1)	-	-	-	-	-	-	-	14.29 (1)	10.00 (1)	14.29 (2)	33.33 (1)	57.14 (4)
Spent	50.00 (1)	44.44 (4)	50.00 (1)	83.33 (5)	-	-	-	-	-	-	-	14.29 (1)	70.00 (7)	35.71 (5)	66.67 (2)	28.57 (2)
F.spent	50.00 (1)	33.33 (3)	-	-	-	-	-	-	-	-	-	71.42 (5)	20.00 (2)	50.00 (7)	-	14.29 (1)

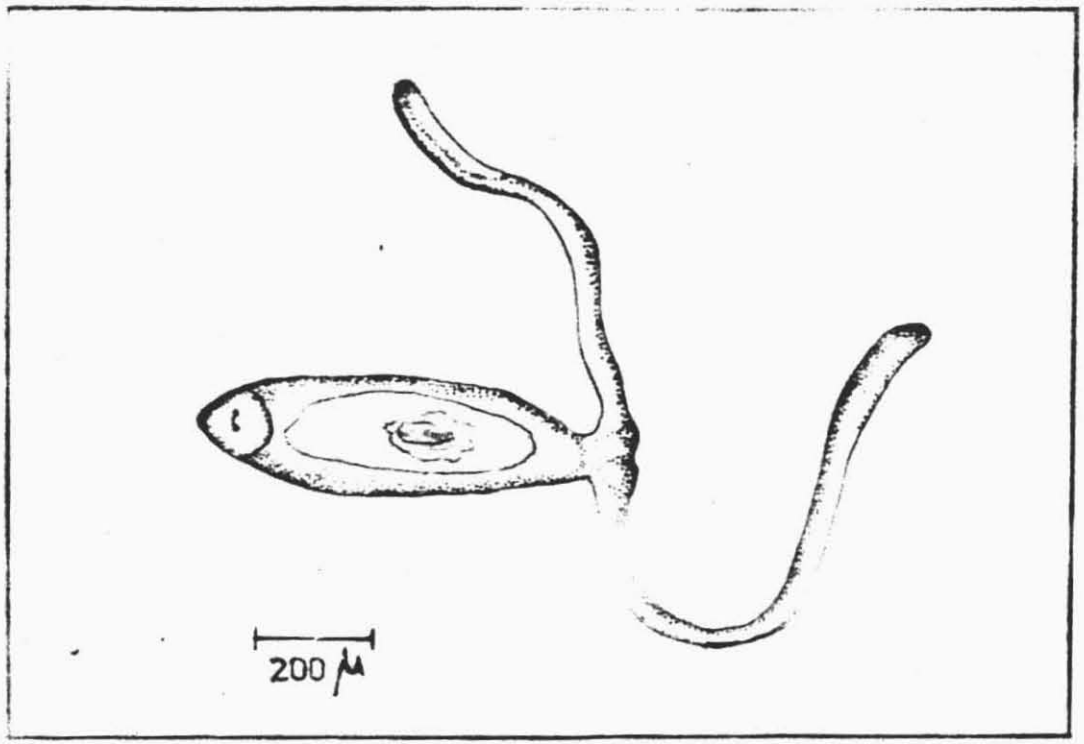
Note : Figures in brackets denotes the number of oysters.

were very few and their percentages were 22.22, 50, and 16.67 for the months of January, February and March '81 respectively. In March '82, the ripe ones seems to be 57.14% during which period, in most of the oysters, gametogenic activity occurs, as a result of which the spent or partly spent individuals were very few. Partly spent infected individuals were found in December '80 and January '81, immediately after the spawning is over and the percentages of partly spent males was upto 50 and 33.33 respectively. In November '81, the partly spent individuals infected with parasites were found upto 71.42% thereafter in the subsequent months it was found to be very low. From this it is clear that the infection starts just at the onset of the spawning of oysters. During this period the gonad may be in a ripe or in partly spent condition. Infection renders the gonad to become sterile, and as such the sex could not be traceable as the parasitic infection advances. In the advanced condition, the cercariae of Bucephalopsis haemeana bear the furcal ramus (Plate.2). The rami are symmetrical, flexible and highly contractile, and their length is several time more than their body length. The cercariae are attached to the tissue of their host by the rami.

SEX RATIO OF OYSTERS INFECTED

Both the males and females were usually found to be harbouring these trematode parasites. The number of

PLATE



Advanced stage of the trematode parasite, Bucephalopsis haemeana observed in the gonad of the oyster, C. [illegible]rasensis

males, females and indeterminates infected with the parasites has been given in Fig. 36 and Table. 32. Infection was found to be very high in the case of females and very low in males during most of the months observed. The percentage of females infected during December '80, January, February and March '81 was calculated to be 78.57, 70.59, 86.67 and 70 respectively. The incidence of parasitism was considerably low in males, i.e., 14.29%, 25.47%, 6.67% and 30% for the months of December '80, January, February and March '81 respectively. Though there was a minor peak of spawning of the oysters during April and May'81, the incidence of parasitic infection was very negligible. During June and July '81 only six female oysters were found with infection. During November and December '81, January, February and March'82, the percentage of infection in female was upto 66.67, 61.11, 41.67, 50 and 36.36 respectively and 33.33, 27.78, 58.33, 30 and 63.64 respectively for males. Among the five months the incidence of infection was found to be dominant in the females during November, December and February, but during January and March alone the male infection was found to be high. On the whole, the incidence of infection was considerably low in the indeterminate oysters.

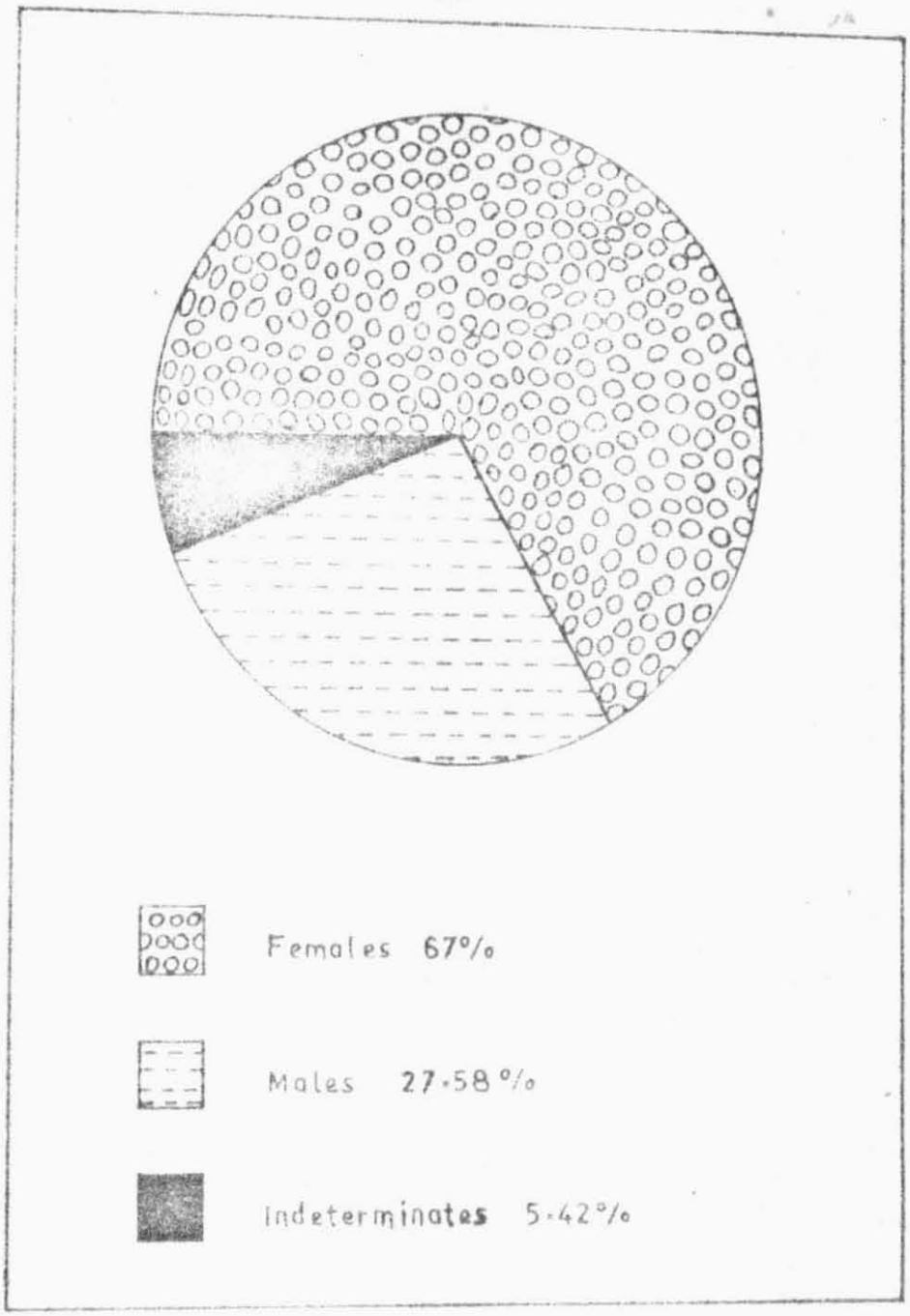


Fig. 36 Percentage of the female, male and indeterminate oysters infected by Bucephalus haemeanas.

Table. 32.

Showing the number of males, females and indeterminate oysters infested with Bucephalus haemeana.

Sex	Dec'80	Jan'81	Feb	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan'82	Feb	Mar	Total	Percent
Female	78.57 (11)	70.59 (24)	86.67 (26)	70.00 (14)	--	--	100 (5)	100 (1)	--	--	--	66.67 (14)	61.11 (22)	41.67 (10)	45.45 (5)	57.14 (4)	136	67.00
Male	14.29 (2)	26.47 (9)	6.67 (2)	30.00 (6)	--	--	--	--	--	---	--	33.33 (7)	27.78 (10)	58.33 (14)	27.27 (3)	42.86 (3)	56	27.58
Indeterminate	7.14 (1)	2.94 (1)	6.67 (2)	--	--	--	--	--	--	--	--	-- (4)	11.11	--	27.27 (3)	--	11	5.42
Total	14	34	30	20	--	--	5	1	--	--	--	21	36	24	11	7	203	100.00

Note : Figures in brackets denotes the number of oysters.

SEASONAL INFECTION

Seasonal variation in the infection of oyster C. mad sensis has been shown in fig. 37. During the period of gametogenic activity no infection was noticed. The infection starts when the gonad is full with ripe ova or in the partly spent condition. In the year 1980, the infection was found to occur just after the spawning of oysters and the percentage of oyster infected during the month of December was 6.9 and it was found to be very high upto 16.75 in January '81. The infection was found to decrease during the month of February and March. In the meantime, gametogenic activity in the oysters started during the month of February and March '81, which resulted in the fall in infection to 14.78% and 9.85% respectively. No infection was found during April and May '81. In June and July the infection was considerably very low and the percentages was 2.46 and 0.49 respectively. Again the infection was not found in the samples analysed during August, September and October '81. Occurrence of the trematode larvae was found during the month of November '81 and the percentage was very low upto 10.34. The oysters, during this period, were at the onset of spawning. The percentage of infection rose to 17.73 during December and came down to 11.82, 5.42 and 3.45 for the months of January, February and March '82 respectively.

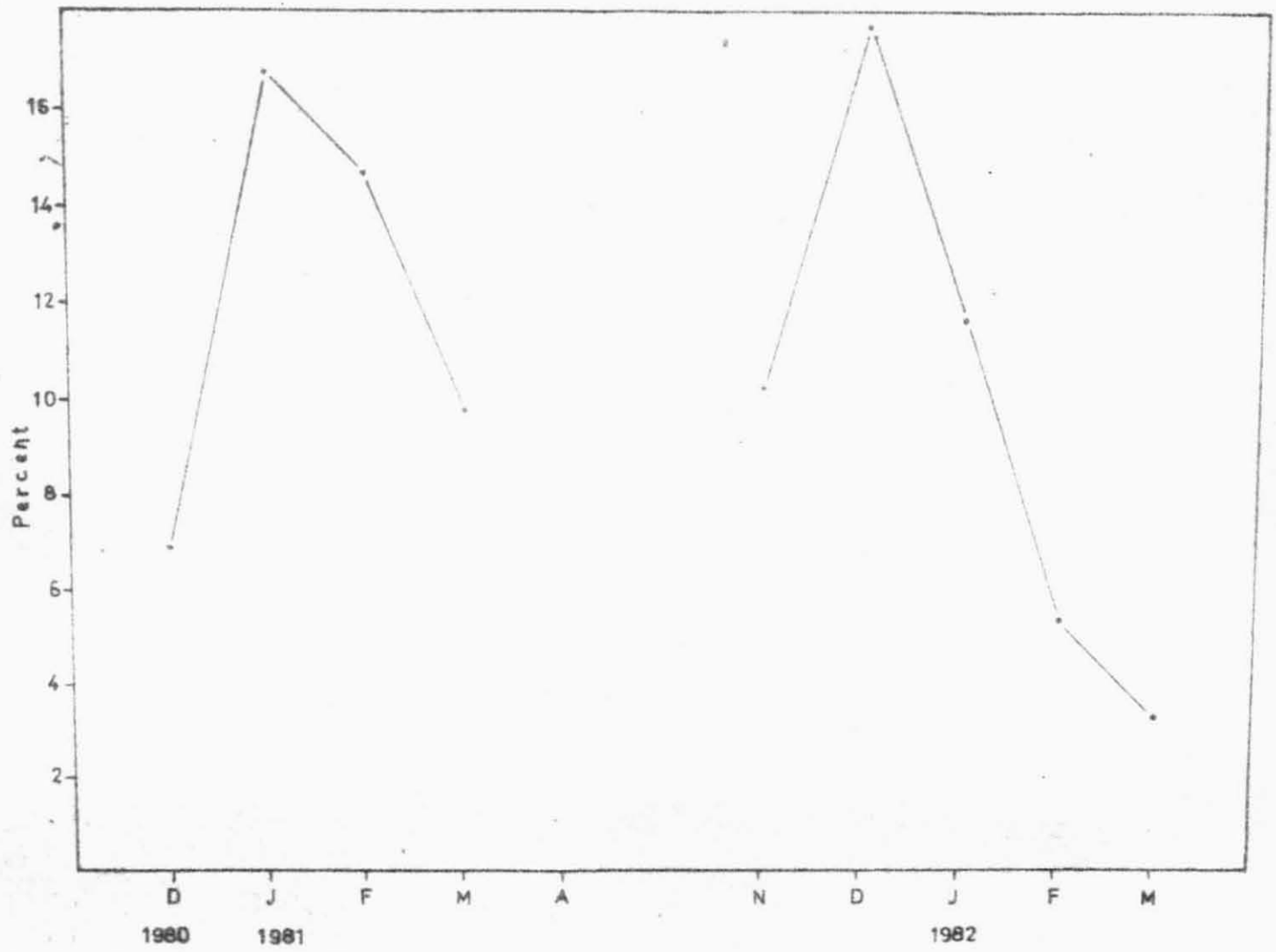


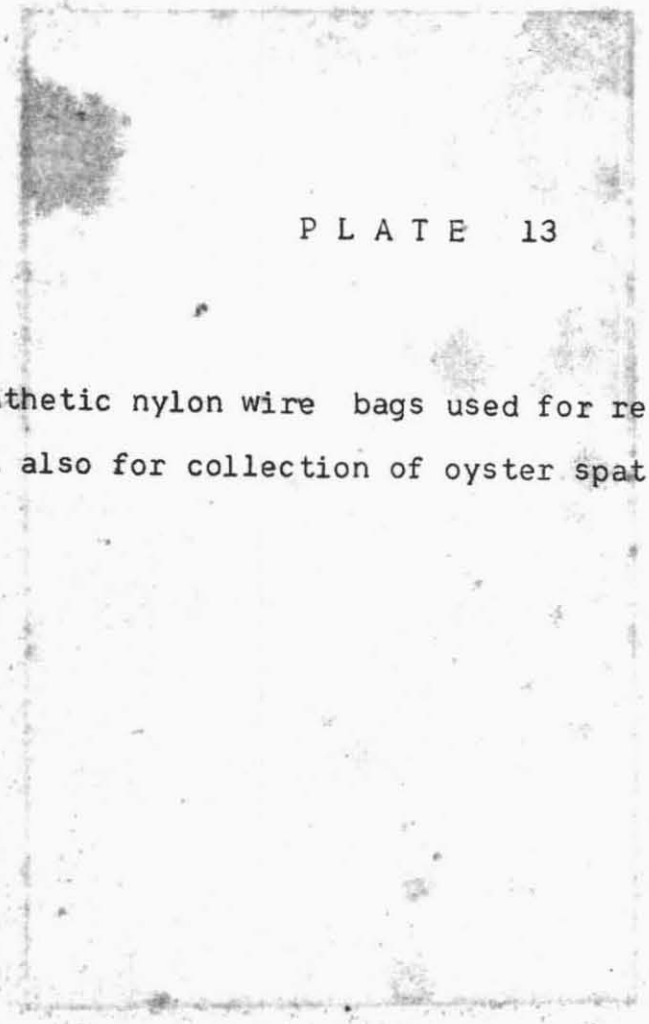
Fig.37 Seasonal variations in the infection of oyster, C. madrasensis by Bucephalus haemeanas

The spawning of oysters was initiated as a result of heavy monsoon rains on the Pulicat lake during the month of November '80 which brought down the salinity to very low levels. It seems to be that the same factor has favoured the adult parasites also to liberate eggs and the resulting miracidia to invade the spent gonad of the oyster. Infection started just after the release of ova during which period the follicular tissue seems to be dilated to a certain extent favouring the attachment of these sporocysts. In 1980, the spawning occurred during the second fortnight of November and the infection was noticed in December. Also in 1981, spawning started in the second fortnight of October and the infection was noticed during the month of November. So it is clear that the North East monsoon triggers off the onset of parasitism and only the partly spent or the spent oysters are mostly subjected to such infection.

EFFECT OF LOW SALINITY ON INFECTION

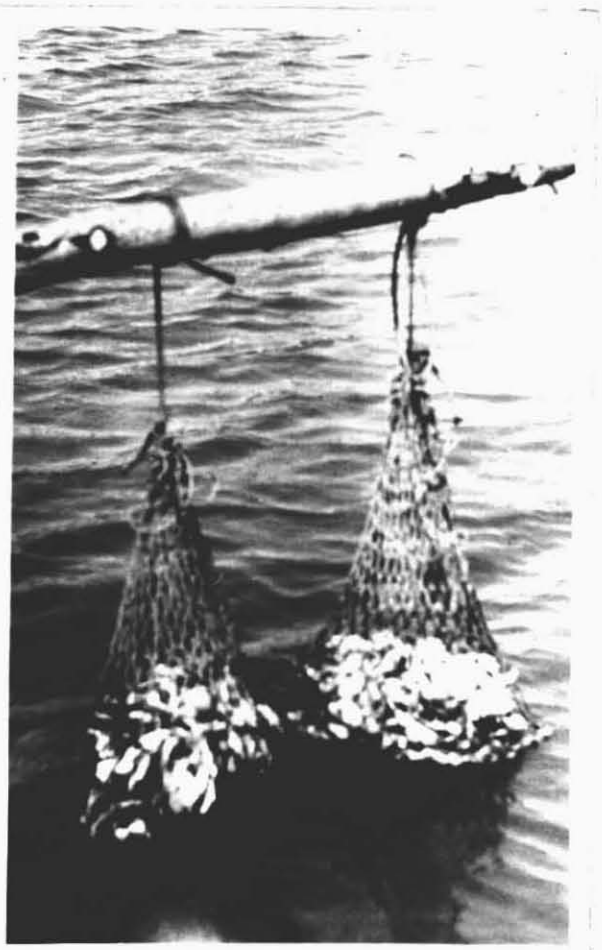
Oysters collected from the natural bed during the first fortnight of November '81 were found to be infected with the trematodes and the salinity in the oyster-bed was observed to be 8.94‰. 713 oysters were collected from the same area and put into six small synthetic wire bags(Plate.13) with the mesh-size of 2 cm. They were suspended into the water opposite to the Estuarine Biological Station, where the salinity of 4.52‰ was considerably lower than in the

P L A T E 13



Synthetic nylon wire bags used for rearing of oysters and also for collection of oyster spat.

PLATE 13



natural bed due to the heavy influx of freshwater. After a period of 17 days, 119 oysters from the bags were examined, and in the meantime salinity declined further to 2.30‰ due to heavy rains on the lake. The percentage of gonad infection was reduced from 12.74 at the start to 0.84, after a period of 17 days. The same sample was continued further for a period of 15 days and was examined to ascertain whether there was any infection. It was found that the oysters were totally devoid of infection and the average salinity for that particular month was observed to be 3.92‰ and the oysters in the natural bed for the same period have shown 10% infection when the salinity in the natural bed was 9.62‰. From this it is inferred that the flood water with a salinity lower than 4.52‰ has its own effect in killing the trematode infection and this agrees with the broad views of Galtsoff (1967) who has mentioned that some of the carnovorous gastropods, flatworms and starfishes which are highly destructive to oysters are killed by the influx of freshwater into the estuary. Ray (1954b) showed that low salinity retarded the development of the terminal infections in laboratory populations. Ray and Chandlier (1955) suggested that exclusively high salinity may be unfavourable for Dermocystidium. Mackin (1956) found a parasitic correlation between high salinity and high incidence of the fungus. So, whenever the trematode infection is noticed, the oysters may be bloated in low saline waters for a week or so, to kill the parasites and the fattening could be done before marketing.

EFFECT ON THE HOST

Usually sporocysts are harboured in the gonad of the host-oysters but in an advanced infection they may invade the other parts such as mantle, gills, hepatopancreas etc.,. As a result of parasitism, the ripe oysters fail to reproduce, owing to partial or complete destruction of the gonads caused by the parasitic infection. Heavy infection of oysters was found to occur during the month of January and December 1981, and most of the infected oysters seem to be lean, flabby and in consistency. They are not considered as palatable during this period. Totally 36 infected oysters were analysed for a study of the gut contents in different months. Among those 57% were found with poor feeding and 43% had moderate quantities of food in their gut. Chang (1967) has pointed out a severe reduction in the amount of stored glycogen in the infected hosts, hence the oysters happen to be lean, watery and less palatable. Menzil and Hopkins (1955a) suggested that the early infections temporarity stimulated the growth of the oyster, but older infections retard the growth. Hopkins (1955a) on the contrary, observed that the infected oysters have an excellent flavour and are fat looking and glycogen-rich throughout the year, whereas the normal oysters are spawned out, thin and relatively tasteless during part of the year. The hyperparasitism produced a blackish discolouration of the oyster mantle and viscera in the American oysters (Mackin and Loesch, 1955). Miller (1963) has

reported that the heavy infection causes almost a total destruction of the gonad, and even a subsequent death of the oyster. Parasitic castration by the trematode Bucephalus cuculus has been reported in the oyster C. virginica(Kinne,1980).

DISCUSSION

The infection of bivalves by several trematodes has been reported by many investigators (Giard, 1897, 1907); Pelseneer (1906); Shipley and Hornell (1904), Southwel (1911, 1912), Ozaki and Ishibashi (1934), Coe (1946) Hopkins(1957), Sakaguchi, 1966b). The invasion of larval trematodes has its effect in reducing the marked population of bivalves (Coe, 1946; Sakaguchi, 1966b). Except the report on the occurrence of the trematode parasite Bucephalopsis haimeanus in the edible oyster by Samuel (1976) and Stephen (1977) no other information is available in India.

In the present study at Pulicat lake, among the various size-groups of oysters examined, the highest percentage of infection upto 15.76 was found in the oysters of the size 60-69 mm and 100-109 mm, and in all other size-groups infection was very low. Usually the young oysters were devoid of parasitic infection.

The incidence of infection was found to be higher in females. Majority of the infected female oysters were found

in the partly spent and spent condition, and males were mostly in partly spent condition. Some of the observations on the infection in the Pulicat lake oysters revealed that the mortality of oysters was not noted as it was reported in other countries, however, as a result of heavy infedtion ova or sperm were resorbed earlier and thus castrating the gonad to an indeterminate stage. As a result, the infected oysters were found to be lean, flabby, watery and low consistency and this agrees with the findings of Ray et al., (1953) and Ray (1954b). Loosanoff (1965) and Hancock and Urguhart (1965) suggested that the Bucephalus might cause parasitic castration and even death of oysters and cockles.

Wesenberg (1974) stated that as a result of the heavy parasitism consumption of food also was heavy. However, in the present investigation on the stomach analysis of the infected oysters of the Pulicat Lake, it was found that 57% of the oysters were with poor feeding and in 43% of the oysters the food in the gut was found to be moderate.

Usually, the maximum percentage of infection was observed during December-January and February-March. No infection was found during the period between August-October '81. The sporocysts are harboured in the gonad of the oyster at first, and in advanced condition they may invade to the other parts of the visceral mass such as mantle, gill, hepatopancreas etc.,. As a result of parasitism, the ripe oysters

fail to reproduce and hence complete destruction of the gonad was caused by the parasitic infection. Hoshina and Ogina (1951) found that as a result of parasitism the physiology of the host is impaired, growth is retarded and reproduction is inhibited. Burton (1956) has concluded that the ova present in the parasitized oysters are resorbed and become sterile. The present observation agrees with the findings of Loosanoff (1965) and Hancock and Urguhart and concluded that the reproductive potential of the oyster is inhibited.

Hoshinga and Ogina (1951) reported that 10 of oysters in the Hiroshima Bay were infected with larval trematode in the gonadal tissues. Hopkins (1954 & 1957) reported parasitism in more than one-third of the oyster population in the United States. Miller (1964) reported the percentage of parasitism was 82.3 . Boyden (1971) has reported the trematode parasitic infection in cockles upto 13.1% and 0.41% in Cerastoderma edule and C. cuculum respectively. According to Samuel (1976) the infection at Karapad during 1976 was 1% and it was 0.61% as observed by Stephen (1977) at Mulki estuary. In the present studies the maximum percentage of infection was 17.73 during December 1981, and 16.75 during January '81, and in all the other months the incidence of infection was very low. This is comparatively higher than the reports of Hopkins (loc.cit.) and Miller (loc.cit.).

The infection starts when the salinity and temperature in the lake decline considerably after the heavy North East monsoon. In the present study, it was also observed that salinity lower than 4.52‰ has its own effect in killing the parasitic trematodes in oysters and this agrees with the view of Galtsoff (1967) who has also mentioned that the gastoropods, flatworms and star fishes which are highly destructive to oysters are killed by the influx of freshwater into the estuary. Ray (1954) also observed that low salinity retarded the development of terminal infection in the laboratory population of oysters.

S U M M A R Y

Plankton analysis of the environment revealed that many of the diatoms appeared to be seasonal, mainly with two peaks in an year, the primary peak during March to April, and the secondary peak during November to December. The diatoms such as Navicula, Nitzschia, Coscinodiscus, Rhizosolenia and Pleurosigma were found throughout the period of observation, fluctuating however in their relative abundance. The range of salinity recorded during the primary peak of diatoms was between 32.2‰ and 39.24‰ and during the secondary peak it was between 0.37‰ and 16.02‰ and temperature was between 28.5°C and 33.5°C, and between 27°C and 32.8°C during the primary and secondary peaks.

The natural food of oysters was composed of 52.8% of diatoms, 45.7% of detritus and 1.5% of animal matter. Two peaks of feeding intensities were observed during the period of the present study, one during December-January and the other during May-June.

Among the diatamaceous food items, the order of preference was Navicula, Coscinodiscus, Nitzschia, Rhizosolenia, Amphora and Peridinium and within zooplankton bivalve veliger rank first followed the ciliate, Tintinnopsis. The oysters showed some sort of preference especially for diatoms like Pleurosigma even when Nitzschia and

Coscinodiscus were found abundant in the environment during May and also for Peridinium and Coscinodiscus when the other diatoms were abundant in the water during June and April respectively. The occurrence of bivalve veligers in the lake and the abundance of veligers present in the gut of oysters showed direct relationship.

The oysters were noted to feed actively at the onset of gametogenesis, but feed poorly during the ripe stages. Oysters feed poorly during the monsoon also, due to prevalence of low saline conditions in the lake. During the post-spawning season, oysters feed actively to meet the energy lost during spawning.

The seasonal variation in the gonads of C. madrasensis (Preston) of the Pulicat lake was studied for two years and it showed three distinct gonadial phases viz., period of gonad development (July-September); period of spawning (October-November) and the spent and indifferent phase (December-January). Gonadal regression was observed to occur during June-July and January-February.

C. madrasensis was observed to be a biannual spawner with a major peak during October-November, and spawning appears to be triggered off by the sudden fall in salinity due to the North East monsoonal rainfall. This is followed by a secondary peak during April-May, the

causative factor for which may be the rise in temperature during summer.

The duration of the gametogenic pattern was observed for a period of four months during the major peak and this was found to be shortened to two and a half months during the minor peak of spawning. The salinity was observed to vary between 31.06‰ and 38.42‰ and temperature from 27.8°C to 30°C, during the period of gametogenesis.

The abundance of males in the natural population was mainly due to the rise in salinity, temperature and also due to the paucity of food in the environment.

The spat settlement studies at Pulicat lake showed that the settlement of the oyster-spat was found to be high during April/May when the salinity was correspondingly high in the lake. The poor settlement of spat observed during October-November was due to the prevalence of low saline conditions in the lake during November. The salinity of the lake seems to be favourable for the growth or larvae and setting during the summer months. Though the number of larvae seems to be considerably high during November, the low salinity does not favour for good settlement.

The biochemical variations such as protein, fat and carbohydrate in the five different body components (mantle, gill, adductor muscle, hepatopancreas and gonad) were

studied to find out the migration of nutrients. The highest protein level in all body components coincided with the fully matured gonad, and low levels during the spent stage. Protein level in all the body components showed fluctuations during the period of observation, but the gonad and hepatopancreas showed higher levels of protein than the other body components.

The protein level in the gonad is high when the gametes are fully ripe, decrease after their release when there is an accompanying increase in the carbohydrate content. The decrease in carbohydrate with increase in protein may be due to conversion of carbohydrate into protein during gametogenesis, During the monsoon period, there is a reciprocal relation between the water content of the body and the biochemical constituents of the animal. This is probably due to the loss of salts and gain of water during this period. Based on the various stages of gametogenesis and their correlation with biochemical levels, it was found that the protein and fat were observed to increase steadily from the II to III stage. This is mainly due to the fast growth of the reproductive elements.

Female oysters were found to contain more lipid content than the males. The high fat level in the hepatopancreas during August was mainly due to high feeding.

In the pre-gravid oysters, the higher amount of fat was observed in the hepatopancreas, but in the gravid ones it was found in the gonad. The reason for the hike in fat during this period was mainly due to the transfer of fat material from the hepatopancreas to the gonad, especially for the formation of gametes. Mantle also acts as an intermediate storage organ for the accumulating fat during high feeding and for supplying it to the gonad at the time of gamete formation. During the present study, accumulation and transfer of energy in the form of fat content was observed from the hepatopancreas and mantle region to the gonad and thus there was a reciprocal relationship between the fat content of the hepatopancreas and the gonad of the oysters.

Carbohydrate was found at its peak during June-July. This was found to decrease gradually during the period of gametogenesis. The mantle appears to store glycogen during the month of July as a result of which it seems to be a thick layer which gets reduced gradually to a thin membrane. Pre-gravid oysters were found to contain large amount of carbohydrate and less lipids and protein. Gravid ones contain large amount of lipid and protein and thus showed a reciprocal relationship in their ratios. It is clearly known from the study that the energy in the form of glycogen is stored in the gonad and hepatopancreas, and

as fat in the hepatopancreas during the primary and secondary peaks of intense feeding. Of all the body components studied, the adductor muscle showed the le st concentration of protein, fat and carbohydrate.

The low intensity of feeding during gametogenesis resulted in the drastic reduction of protein in the gonad and hepatopancreas of the males, but in females, the process of maturation of gametes also was slowed down.

Study of nucleic acids and their importance in the biology of oysters has been attempted during the present investigation. There are no statistically significant variations in the quantity of RNA, DNA and phosphorus contents of the male and female oysters. The RNA and DNA contents showed an inverse relationship in all the body components. The RNA content showed two peaks, the primary one during June, and the secondary one in January-February. The DNA and phosphorus contents showed their primary peak during October and the secondary one during April. The gonad and hepatopancreas showed the highest concentration of RNA during the entire period of observation. The lowest concentration of DNA was in the adductor muscle throughout the period of observation. The gill and mantle showed low but more or less equal quantities of DNA. The highest concentration of DNA was registered in the gonad and hepatopancreas. The maximum quantity of phosphorus was

observed in the hepatopancreas during the entire period of observation and the lowest concentration was in the adductor muscle throughout the period of observation.

The DNA content was very low at the beginning of the gametogenesis and the RNA content showed a gradual decrease from the I stage to the ripe condition. During the regressive condition of the gonad, both the DNA and phosphorus contents were resorbed into the body and this reduction was represented by a hike in their concentration in the hepatopancreas and gonad. The RNA content coincides with the peak period of intense feeding and low feeding coincides with low RNA, but the DNA content does not show any such relationship with feeding intensity.

The synthesis of large amounts of RNA during the early stages of gametogenesis is suggested to be due to the utilisation of this RNA for the endogenous synthesis of protein as revealed by the increasing trend of protein from the I stage of oocyte development onwards.

The phosphorus content increases and reaches the peak during the active period of gametogenesis and the same was found to decrease during the spawning season due to the extrusion of a large number of sex products. During the regressive condition the phosphorus content showed very feeble rise in the mantle, gonad and adductor muscle, but in hepatopancreas, there was a considerable hike in the

concentration of phosphorus indicating the resorption of the same from the unspawned gonadial elements.

Based on meat weight ratio of different size-group of oysters, commercial harvesting of 61-80 mm size-group may be more profitable than the other size-groups. The maximum weight was observed during the month of July and January, as a result of accumulation of glycogen and during the months of October and April due to the high protein content in the oysters. Among the body components, mantle forms a prominent body component. Seasonal variations in the index of gonad, hepatopancreas and mantle were studied. The gonad-index and the digestive gland-index showed an inverse relationship during the entire period of this study. The digestive gland-index is higher than the gonad-index during the vegetative phase of the life cycle.

The water content was ranging between 72.08% and 82.5% during this period of study. It was found to be higher in the gills than in the other body components. The water content during the period of gametogenesis in the gonad was lower than in the hepatopancreas. It increases immediately after spawning, indicating a reciprocal relationship between the water content of the gonad and of the hepatopancreas. The water content was low in the mantle at the time of the ripe condition of gonad, but the mantle is thin, watery, transparent and flabby immediately after spawning.

The dry weight of the hepatopancreas and gonad seems to be higher than that of the other body components. There is a gradual increase in the body weight during the period of gametogenesis reaching its peak during the fully ripe condition and declines sharply after spawning.

The digestive gland-index was found to increase as a result of accumulation of energy when there was high feeding and declines slowly as a result of supply of nutrients to the gonad at the onset of gametogenesis. In C. madrasensis, the flesh weight declines along with biochemical constituents such as protein, fat, carbohydrate and DNA during May and November due to the extrusion of a large number of gametes.

During the present study, trematode parasitism was observed in the gonads of the oysters from December 1980 to March 1982. Maximum percentage of infection was 17.73 during December. Infection was not found during April to May, and during August to October. The maximum intensity of infection was observed in the size-groups of 60-69 mm and 100-109 mm. Individuals below 60 mm and more than 100 mm show very poor infection. This is probably due to the age related immunity in the case of fully grown oysters and the poor development of gonad in the case of young ones. The change of habitat and feeding behaviour of the host are suggested to be the reasons for the lower incidence of parasites.

Initially, the infection was noticed in the gonad of the oysters, and as it advances, it invades the other tissues such as mantle, gill and digestive gland etc.,. Infection was found in the fully ripe ones, but it was more in the partly spent and in the spent individuals than in the individuals with gametogenic activity. As a result of infection, ova or sperms are resorbed quickly and thus oysters are castrated to an indeterminate stage. In the majority of the infected oysters, feeding was noted to be very poor. Among the infected oysters, the percentage of infected females was higher than the infected males.

The infection seems to be seasonal and starts when the salinity and temperature in the lake decline considerably, after the heavy North East monsoon rains. It has been experimentally observed that salinity below 2.3‰ kills the trematode infection in the oysters.

REFERENCES

Abraham, K.C. 1950. Observations on the biology of Meretrix casta (Chemnitz). J. Zool. Soc. India, 5 : 163-190.

Agastheesapillai, A and T. Subramoniam, 1980. A comparative study on oogenesis of two marine bivalves, Crassostrea madrasensis and Perna viridis. Symposium on Coastal Aquaculture, Cochin, J.M.B.A.I. Abstract No. 59.

Alagarswami, K. 1966. Studies on some aspects of the biology of the wedge-clam, Donax faba Gmelin from Mandapam coast in the Gulf of Mannar, J. Mar. biol. Ass. India, 8 (1) : 56-75.

Allen, M.J. 1967. Nucleic acid and protein synthesis in the developing oocytes of the budding form of the Syllid Autolytus edwardsii (Polychaeta). Biol. Bull. 133 : 287 - 302.

Amemiya, I. 1925. 'Hermaphroditism of the Portuguese Oyster' Nature, 1925, 116-608.

Amemiya, I. 1926. Notes on experiments on the early developmental stages of the Portuguese, American and English nature oysters with special reference to the effect of varying salinity. Jour. Mar. Biol. Ass., N.S., 14 : 161-175.

Amemiya, I. 1928. Ecological studies of Japanese oysters with special reference to the salinity of their habitats. Jour. Coll. Agric. Imp. Univ., Tokyo. 9 334-382.

Amemiya, I. 1929. On the sex change of the Japanese common oyster, Ostrea gigas Thunberg. Proceedings of the Imperial Academy of Japan. 5 : 284-286.

Andrews, J.D. 1971. Climatic and ecological settings for growing shellfish. Proc. Conf. Artif. Propag. Commer. Valuable Shellfish, Coll. Mar. Stud., Univ. Delaware pp 77-108.

Andrews, J.D. 1966. Oyster mortality studies in Virginia, V. Epizootiology of MSX, protistan pathogen of oysters. Ecology 47, 19 - 31.

Ansari, Z.A; A.H. Parulekar and S.G.P. Matondkar, 1981. Seasonal changes in meat weight and biochemical composition in the Black clam Villorita cyprinoides(Grey). J. mar. Sci., 10, pp 128-131.

Ansell, A.D. 1961. Reproduction, growth, and mortality of Venus striatula in James Bay, Millport. J. Mar. biol. Ass. U. K., 41 : 191-215.

Ansell, A.D. 1972 Distribution growth and seasonal changes in the biochemical composition of the bivalve Donax vittatus (Da costa) from Dames Bay, Millport. J. Exp. Mar. Biol. Ecol., 10 : 137-150

Ansell, A.D. 1974a. Seasonal changes in biochemical composition of the Bivalve, Abra alba from the Clyde Sea Area. Mar. Biol. 25, 13-20.

Ansell, A.D. 1974b. Seasonal changes in Biochemical composition of the bivalve Chlamys septemradiata from the Clyde Sea Area. Mar. Biol. 25, 85-99.

Ansell, A.D. 1974c. Seasonal changes in the biochemical composition of the Bivalve Nucula sulcata from the Clyde Sea Area. Mar. Biol. 25, 101-108.

Ansell, A.D., F.A. Loosemore, and K.F. Lander, 1964. Studies on the hard shell clam, Venus mercenaria in British waters. II. Seasonal cycle in biochemical composition J. Appl. Ecol., 103 : 83-95.

Ansell, A.D., K.F. Lander, 1967. Studies on the hard shell clam, Venus mercenaria in British waters. III. Further observations on the seasonal biochemical composition and on spawning. J. Appl. Ecol., 4 : 425-435.

Ansell, A.D., and Trevallion, A. 1967. Studies on Tellina tenuis Da Costa. Seasonal growth and biochemical cycle. J. Exp. Mar. Biol., Ecol. 1, 220-235.

Ansell, A.D., Sivadas, P and Narayanan,B. 1973. Special publication, Mar. Biol. Ass. India . 338.

Ansell, A.D., L. Frenkiel; and Moueza, 1980. Seasonal changes in tissue weight and biochemical composition of the bivalve Donax trunculus L. on the Algerian coast. J. Exp. mar. Biol. Ecol., 45, 105-116.

Antony Raja, B.T. 1963. Observations on the rate of growth, sexual maturity and breeding of four sedendary organisms from the Madras harbour. J.Mar. biol. Ass. India 5, 113-132.

Ashikaga, C. 1948. Biochemical studies on the pearl oyster Pinctada martensii. I. The seasonal variation of the chemical composition, especially of glycogen constituents, Seiro-Seitai, 2, 160-167.

Antunes,S.A., and Ito,Y., 1968. Chemical composition of oysters from Sao Paulo and Parana, Brazil. Biol.Inst. Oceanogr., 17(1) : 71-88.

Asif, M. 1979. Hermaphroditism and sex reversal in the four common oviparous species of oysters from the coast of Karachi, Pakistan. Hydrobiologia 66(1) : 49-56.

Asif, M. 1980. The reproductive cycle in the population of Saccostrea cucullata from the coast of Karachi,Pakistan. Hydrobiologia 68 (1) : 73-80.

Awati, P and Rai, H , 1931. Ostrea cucullata (The Bombay oyster) Indian Zool. Mus, 3 : 107 pp.

Baker,M.E.T; Boyd, E.M., Clarke, E.L., and Ronan, A.K. 1942. Variations in the water, fat, glycogen and iodine of the flesh of oysters (Ostrea virginica) during hibernation and storage at 4°C. J. Physiol (London) 101, 36-43.

Balasubramanian, R. 1970. Studies on the pholadid marine wood borer, Martesia striata (Linn.). Proc. Symp. Mollusca, Cochin, 1968. Mar. Biol. Assoc. India. Symp. Ser.3 Part . . 707-711.

Bardach, J.E., Ryther, J.H., Mcharney, W.O. 1972. 'Aquaculture the Farming and Husbandry of Rreshwater and marine organisms' pp. 674-742. Wiley (Interscience) New York.

Bargeton, M. 1942. Les variations saisonieres due tissue conjonctif vesiculeur de l'huitre, Bulletin Biologique de la France et de la Belgique 76(2) : 175-191.

Bargeton,M. 1943. Modification histologiquesde la zone des gonads spres la ponte chex Gryphaea angulata Lamk. Bulletin Biologique de la France et de la Belgique 77: 97-103.

* Bargeton, M. 1944. Bull. Mus. Hist. nat., Paris, 16 :378-381.

Bayne, B.L. 1965. Growth and the delay of metamorphosis of the larvae of Mytilus edulis(L) Ophelia 2, 1-47.

Bayne, B.L. 1975. Reproduction of bivalve molluscs under environmental stress. In 'Physiological Ecology of Estuarine organisms' (F.J.Vernberg, ed), pp.259-277.

Bayne, B,L. 1976a. Aspects of reproduction in bivalve molluscs.In' Estuarine Processes, Vol.1 : Uses, stresses, and adaptations to the Estuary' (M. Wiley, ed.).

Bayne, B.L. 1976b. 'Marine Mussels; their Ecology and physiology, International Program, 10. Cambridge. Univ. Press London and New York.

Bayne, B.L. and Thompson, R.J. 1970. Some physiological consequences of keeping Mytilus edulis in the laboratory Helgol. Wiss. Meerisantens 20, 526-552.

Bell, F.W. 1970. The future of the Worlds Fishing Resources; forecast of the demand, supply and prices to the year 2000 with a discussion of implication of Public policy. Economic Research Laboratory. National Marine Fisheries Service, File Manuscript. 419pp.

Bertout,M and Dhainaut, A 1971. Etude cytochimique et autoradiographique de l'ovogenase de Nereis diversicolor O.F. Muller (Annelida : Polychaeta) dans les conditions naturelles et en l'bsenie d'hormone cerebrate. Gen. comp. Endocrind 17: 373-387.

Blackmore,D.T. 1969. Studies on Patella vulgata.1. Growth, reproduction and zonal distribution J.Expt. Mar. Biol. Ecol., 3 : 200-213.

Blegvad, H. 1914. Undersog lser Naering og Ernaerings for for hold los Havbundens invertebrate Dyresamfundi dansk. Fraevende. Ber. Dan. Biol stn. 22,41-78.

Boyden, C.R, 1971. A comparative study of the reproductive cycles of the cockles, Cerastoderma edule and C.glaucu J. Mar. Biol. Assoc. U.K. 51, 605-622.

Bonilla Ruiz, J.1975. Monthly variation in the chemical composition of mangrove oysters in the Las Maritas lagoon (Venezeula). Biol. Inst. Oceanogr. Univ. Oriente Cuma 14(1) : 117-128.

Bonnot,P 194L. Methods of collecting oyster spat. Trans.Am. Fish. Soc. 69 : 263-267.

Brachet, J. 1955. The biological role of the pentose nucleic acids, P. 475-519. In E. Chargoff and J.N. Davidson(e The nucleic acids, Chemistry and biology Vol.2. Academ Press ; Inc; New York, NY.

Brukema,J.J and De Brunn,W 1977. Seasonal changes in dry weight and chemical composition of the soft parts of th tellinid bivalve Macoma balthica in the Dutch Wadden S Neth. J. Sea. Res. 11, 42-55.

Bulow, F.J. 1970. RNA-DNA ratios as indicators of recent grow rates of a fish. J. Fish. Res. Board Can. 27: 2343-23

Burkenroad, M.D. 1931. Sex in the Lousiana oyster, Ostrea virginica, Science 74 :71.

Burton, K. 1956. Biochem. J. 62, 315

Butler, P.A. 1949. Gametogenesis in the oyster under conditio of depressed salinity. Biol. Bull., 96(3): 263-269.

Butler, P.A. 1955. Reproductive cycle in native and transplanted oyster. Proc. nat. Sellf. Assn., 46-75.

Calabrese, A. 1969. Reproductive cycle of the root clam, Mulinia lateralis (Say) in Long Island Sound, Veliger 12, 265-269.

Calvin, D.B. 1931. Glycogen content of freshwater mussels. Proc. Soc. Exptl. Biol. Med. 79, 96-97.

Capco, D.G and Jeffery,W.R. 1976. Origin and spatial distribution of Maternal Messenger RNA during oogenesis of an insect, Oncopeltus fasciatus. J. Cdl.Sci.39: 63-76.

Carriker, M.R. 1951. Origin and spatial distribution of oyster larvae in New Jersey estuaries. Ecol. Monogr. 21,19-38.

Chacko, P.I. 1954. Ind. Com. Journal vol. IX No.2.

Chacko,P.I., Abraham, J.G.,and Andal,R. 1953. Report on a Fishery survey, Fauna and Fisheries of the Pulicat lake Madras State India, 1951-1952. Contr. Freshwater Fish. Biol. Stat., Madras, 8 : 1.

Cheelaman, V.M and Tomlinson. 1959. Biochemical studies on sockeye salmon-during spawning migration. VI. Ribonucleic and deoxyribonucleic acids. J. Fish. Res. Board. Can. 16: 421-428.

Cheng, T.C. 1965. Histochemical observations on changes in th lipid composition of the American oyster, Crassostrea virginica(Gmelin) parasitized by the trematode Bucephalus sp. J. Invertebrate Pathol. 7, 398-407.

Chifferfield,P. 1953. Observations on the breeding and settlement of Mytilus edulis (L) in British waters. J. Mar. Biol. Assoc. U.K. 32, 449-476.

Cleland, K. W. 1947. Some observations on the cytology and oogenesis in the Sydney rock oyster (Ostrea commercialis I δ R). Proc. Linn. Soc. N. S. W. 72: 159-182.

Coe, W.R. 1932a. Development of the gonads and the sequence of the sexual phases in the Californian oyster(Ostrea lurida). Bull. Scripps Instn. Oceanogr. Tech. 3: 119-144.

Coe, W.R. 1932b. Sexual phases in the American oyster (Ostrea virginica). Biol. Bull., Woods Hole 63 : 419-441.

Coe, W.R. 1934. Alternation of sexuality in oyster, American Naturalist. 68 : 236-252.

Coe, W.R. 1936. Sequence of functional sexual phases in Teredo; Biol. Bull., 71: 122-132.

Coe, W.R. 1943. Sexual differentiation in molluscs I. Pelecypods Quart. Rev. Biol. 18: 154-164.

Coe, W.R. 1945. Development of the reproductive system and variations in sexuality in Pecten and other Pelecypod molluska. Trans. Conn. Acad. Sci. 36, 673-700.

Coe, W.R and Turner, H.J., Jr. 1938. Development of the gonads and gametes in the soft shell clam (Mya arenaria) J.Morph. 62 : 91-111.

Cole, H.A. 1939. Further experiments in the breeding of oysters (Ostrea edulis) in tanks. Fishery investigations. Ministry of Agriculture., Food and Fisheries, Series 2 16(1) : 1-51.

Cole, H.A., and Knight-Jones, E.W. 1949. Some observations and experiments on the setting behaviour of larvae of Ostrea edulis. J. Cons Perm. Int. Explor. Mer.14: 86-105.

Cole, H.A. 1942. 'Primary sex-phases in Ostrea edulis' Quart. J. Micr. Sci. 83 : 317-356.

Collip, J.B. 1921. J. Biol. Chem., 49: 297.

Comely, C.A. 1974. Seasonal variation in the flesh weights and biochemical content of the scallop, Pecten maximus(L) in the Clyde Sea area. J. Cons. Perm. Int.Explor.Mer. 35, 285-295.

Couteaux-Bargeton, M., 1947. Bull Soc. Zool, Fr., 71, 121-126.

Cranfield, H.J. 1970. Some effects of experimental procedure on settlement of Ostrea lutaria Hutton. N. Z.Jl. Mar. Freshwat. Res. Vol. 4. 63-69.

Croft, H.G. 1968. Tray cultivation of oysters. Fisherman 3(1) 12-14.

Daniel, R.J. 1922. Seasonal changes in the chemical composition of the mussel (Mytilus edulis) Rep. Lancashire Sea, Fish, Lab. pp27-50.

Dare P.J. and Edwards, D.B. 1975. Seasonal changes in the flesh weight and biochemical composition of mussels (Mytilus edulis L) in Conway estuary, North Wales. J. Exp. Mar. Biol. Ecol. 18, 89-97.

Das, N.K; Luykx,P . Alfert, M. 1965. The nucleolus and RNA metabolism in Urechis eggs, Develop. Biol. 17,72-78.

Das, N.K. 1968. Developmental features and synthetic patterns male germ cells of Urechis caupo. Arch.Entwicklungsmech. Organismen. 161, 325-335.

*Davaine, C. 1953. 'Rechercehs sur la generation des huitres'. J. Conchybiol., 4 : 30-32.

Davenport, R. 1976. Transport of ribosomal RNA into oocytes of the Milkweed Bug, Oncopeltus fasciatus. J. Insect. Physiol. 22: 925-926.

Davidson, E.H., Allfrey, V.G., and Mirsky,A.E. 1964. On the RNA synthesized during the compbrush phase of amphibian oogenesis. Proc. Nat. Acad. Sci. U.S.52: 501-508.

Davis, H.C. 1953. On food and feeding of larvae of the American oyster, C. virginica. Biol. Bull.(Woods Hole, Mass) 104, 334-350.

Davis.F.C., Jr. and Wilt,F.H. 1972. RNA synthesis during oogenesis in the echiuroid worm Urechis caupo. Develop. Biol. 27, 1-12.

Davis,H.C and Guillard,R.R 1958. Relative value of ten genera of micro-organisms as food for oyster and clam larvae U.S. Fish. Wildl. Serv; Fish. Bull, 136, 293-304.

Desai,K, Bhatt, S and Nimavat,D, 1979. Ann. Zool (Agra).

Deshmukh,R.S. 1972. Some aspects of the biology of Meretrix meretrix Ph.D Thesis- Marathwada University, India. 86-115,

Devanesan,D.W and P.I. Chacko. 1955. On the Madras edible oyster (Ostrea madrasensis) Cont.Fish. Biol. Stn., Rept. Fish., Madras, 2, 60pp.

De Zwann, A and Zandee, D.I. 1972. Body distribution and seasonal changes in glycogen content of the common sea mussel Mytilus edulis. Comp. Biochem. Physio,. A43,53-58

* Dhainaut, A. 1965. Contribution a l'etude due metabolisme de l' A.R.A., par incorporation de ^{3}H- Uracile, all cours de

l'ovogenese echez Nereis diversicolor (O.F.Muller), Bull. Soc. Zool. Fr. 89, 408-413.

Dinamani,P. 1974. Reproductive cycle and gonadial changes in the New Zealand Rock Oyster Crassostrea glomerata N. Z. J. Mar & Freshwat.Res. 8(1) : 39-65.

Dix, T.G. 1975. Farming the sea. In : M.R. Banks and T.G.Dix (Editors), Resources of the sea. Symposium of Royal Society of Tasmania, November, 1974 pp 93-100.

*Dollfus,R.P, 1923. Le maladie des moules et la mortalite' des huitres en Zelande an course de ces dernieres annees. Bull. Soc. Cent. Aquacult. Peche 30, 38-44.

*Dotterweich, H and Elseneer,E. 1935. Biol. Zbl., 55:c138.

Durve, V.S. 1964a. On the percentage of edibility and the index of condition of the oyster Crassostrea gryphoides (Schlotheim). J. Mar. biol. Ass. India.1964,6(1):128-135

Durve, V.S. 1964b. A note on the food of the oyster Crassostrea gryphoides (Schlotheim). Curr.Sci. 33 : 434-435.

Durve, V.S. 1964c. Preliminary observations on the seasonal gonadal changes and spawning in the clam Meretrix casta (Chemnitz) from the marine fish farm. J. Mar. biol. Ass. India 6 : 241-248.

Durve, V.S and Bal.D.V 1961. Studies on the chemical composition of the oyster, Crassostrea gryphoides (Schlotheim) J. Zool. Soc. India, 13(1) : 70-77.

Durve, V.S and Bal, D.V. 1964. Preliminary observations on the growth and spat of the oyster Crassostrea gryphoides (Schlotheim) J.Mar.biol. Ass.India, 4 : 206-213.

Estabrook, S.L. 1973. Seasonal variation in the glycogen and lipid content of the bay scallop, Aequipecten irradians Lamarck. M.S. Thesis North Eastern Univ., Boston, Massachusetts.

Evangeline, G. 1966. Fouling organisms of the edible oyster cultch in the Ennur Backwaters. Madras J. Fish. Vol. II July 1966, p 64-68.

Fischer. P.H. Casses de destruction des mollusques : Maladies et mort, J. Conchyliol, 91, 29-59.

Fiske, G. H. and Subba Row, Y. 1925. J. Biol. Chem. 66: 375.

FOLCH, J., LEES, M. JARBACK, B.F. and SLOANE, G.H. 1957. J. Biol. Chem., 226, 497.

Fraga, F. 1956a. Average seasonal variation of chemical constituents of the mussel (M. edulis). Repp. P.V. Reun., Cons. Int. Explor. Mer. 140, 35.

Fraga, F. 1956b. Variacion estacional dela composicion quimices del majillion (Mytilus edulis). (Seasonal changes in the chemical composition of the mussel). Invest. Pesq., 4: 109-125.

Fraga, F. 1956c. Variacion estacional dela composition of quimices del majillion (Mytilus edulis). II. Hidrates de carbon. (Seasonal varation in the chemical composition of the mussel. II Carbohydrate Invest Pesqs : 11 33-34.

Fretter, V and Graham. A. 1964. Reproduction. In 'Physiology of Mollusca'. Vol. I. Wilber, M.M and C. M. Yonge(ed). Academic Press, New York and London.

Fuji, A. 1957. Growth and breeding season of the brackish water bivalve, Corbicula japonicum, in Zyoson Gote inlet. Bull. Fac. Fish. Hokkaido Univ. 8(3), 178.

Fujita, T., Matsubara, T., Hirokawa and Araki, F. 1955. On the inflammatorious changes of the Ostrea gigas in Hiroshima Bay. (in Japanese with English summary) Bull. Japan Soc. Sci, Fisheries 20, 1063-1065.

Fujita, T., Takayuki, M., Hirokawa, Y., and Fumio, A. 1953. Pathological histological studies of the inflammation in Hiroshima Bay oysters (Ostrea gigas). J. Japan Fisheries Soc. 19, 766-770.

Fujiya, M. 1971. Oyster farming in Japan. Helgol. Wiss. Meeresunters,, 20 : 464-479. Japan Fisheries Association, San Kaido bodg., 9-13 Akusada 1, Minait- Tokyo 44pp.

Gabbott, P.A. 1975. Storage cycles in marine bivalve molluscs : A hypothesis concerning the relationship between glycogen metabolism and gametogenesis. Proc. Eur. Mar. Biol. Symp., 9th Oban, Scotland, pp. 191-211.

Gabbott, P.A. 1976. Energy metabolism. In 'Marine Mussels' (B.L. Bayne, ed), pp. 293-355. Cambridge Univ. Pres London and New York.

Gabbott, P.A. and Bayne, B.L. 1973. Biochemical effects of temperature and nutritive stress on Mytilus edulis. J. Mar. Biol. Assoc. U.K. 53, 269-286.

Galtsoff, P.S. 1930a. Destruction of oyster bottoms in Mobile Bay by the flood of 1929. U.S. Bureau of Fisheries Report of the Commissioner of Fisheries for the fiscal year 1929, appendix 11 (Document-1069) pp. 741-758.

Galtsoff,P.S. 1930b. 'The role of chemical stimulation in the spawning reaction of Ostrea virginica and Ostrea gigas'. Proc. Nat. Acad. Sci., Washington 1930, 555-559.

Galtsoff, P.S. 1932. Introduction of Japanese oysters into the United States. U.S. Bureau of Fisheries, Fishery Circular No. 12, 16pp.

Galtsoff, P.S. 1935. 'Factors governing propagation of oysters and other marine invertebrates'. Proc. Fifth. Pacific Sci. Cong., Canada, 1933, 5.

Galtsoff, P.S. 1938. 'Physiology of reproduction of Ostrea virginica 1. Spawning reaction of the female and male', Biol. Bull., 1938, 74, 464-486.

Galtsoff, P.S. 1964. The American Oyster Crassostrea virginica (Gmelin) : Fishery Bulletin of the Fish and Wildlife service. 64. U.S. Government Printing office, Washington 25, D.C. pp. 480. A detailed and extensive account of the anatomy and physiology of this species.

Giese, A.C. 1966. Lipids in the economy of marine invertebrates. Physiol. Rev. 46, 244-298.

Giese, A.C. 1967. Some methods for study of the biochemical composition of the marine invertebrates. Oceanogr. Mar. Biol. 5, 253-288.

Giese, A.C. 1969. A new approach to the biochemical composition of the mollusc body. Oceanogr. Mar. Biol : 7 : 175-229.

Giese, A.C. and Araki, G.S. 1962. Chemical changes with reproductive activity of the chitons, Katherina tunicata and Mopalia hiurdsii. J. Expt. Zool., 151-59.

Giese, A.C. and Hart, M.A. 1967. J. Expt. mar. Biol. Ecol. 1 : 34.

Giese, A.C., Hart, M.A., Smith, A.M and Cheung, M.A. 1967. Seasonal changes in body component indices and biochemical composition in the Pisma clam, Tivella stultorum. Comp. Biochem. Physiol., 22, 549.

Giese, A.C. and S. Pearse. 1975. Reproduction of Marine invertebrates Vol. III. Annelids and Echiuroids. Academic Press, New York. 343 pp.

Gimazane, S.P. 1972. Etude experimentale de l'action de quelques facteus extremes sur la reprise de l'activite' gènitale' de la coque, Cerastoderma edule L. Mollusque Bivalve. C.R. Soc. Biol. 166, 587-589.

Goromosova,S.A. 1968. Seasonal changes of the chemical composition of the Black sea oysters. Gidrobiol.Zh.,4(3): 72-76.

Gould, M.C. 1969. RNA and protein synthesis in fertilised and unfertilised eggs of Urechis caupo. Develop. Biol. 19, 482-497.

Greenfield, L. J. 1953. Observations on the nitrogen and glycogen content of Teredo (Lyrodus) pedicellata at Miami, Florida. Bull. Marine Sci. Gulf Caribbean, 2, 486.

Gross, P.P., Mackin,L.I, and Hubbard, M. 1965. Synthesis of RNA during oogenesis in the sea urchin. J. Mol. Biol. 13, 463-481.

Gunter, G. 1957. Temperatre. Geol. Soc. Am., Mem,67, 159-184.

Haskin, H.H. 1964. The distribution of oyster larvae. Occ. Publs. mar. Lab., Narragansett. 2 : 76-80.

Hewatt, W.G., and Andrews, J.D. 1956. Temperature control experiments on the fungus disease, Dermocystidium marinum of oysters. Proc. Natl. Shellfisheries Assoc. 46, 129-133.

Hatanaka, M. 1940. Chemical composition of the oyster, Ostrea gigas. Bull.Japan Soc.Sci. Fisheries, 9, 21.

Hawks, P.B, Oser, B.L., and Summerson, W.H. 1954. Practical physiological chemistry, McGraw-Hill Book Co., Inc. New York.

Hidu, H., and Hasmin, H.H. 1972. Setting of the American oyster related to environmental factors and larval behaviour. Proc. Natl. Shellfish. Assoc. 61, 35-50.

Higashi,H., 1936. F. Imp. Fish. Exp. Sta. pp. 209-31.

Hinegardner, R.T. 1968. Amer. Naturalist. 102, 517-523.

Hinegardner, R.T. 1971. Analytical Biochemistry, 39, 197-201.

Hinegardner, R.T. 1974. Comp. Biochem. Physiol., 1974, vol.47A, pp. 447-460. Pergman Press. Printed in Great Britain.

Hinegardner,R.T and D.E. Rosen. 1972. Amer. Naturalist 106, pp. 621-644.

Hoek, P.P.C. 1883. Oyster culture. Great international Fisheries Exhibition, The fisheries literature Vol.II Prize essays, Part 4, No.4, 36 pp. Clowers and Sons, London.

Holland, D.L. and P.J. Hanonaut, 1976. The glycogen content in winter and summer oyster, Ostrea edulis L. of different ages. J. cons.int. Explor. Mer. 36(3): 240-242.

Holm-Hansen, O., W.H. Sutcliffe,Jr and J. Sharp. 1968. Measurement of deoxyribonucleic acid in the ocean and its ecological significance. Limnol. Oceanogr. 13: 507-514.

Hopkins, A.E. 1931. Temperature and the shell movement of oysters. Bull. U.S. Bur. Fish., 47. 1-14.

Hopkins, A.E. 1937. Experimental observation on spawning larval development, and setting in the Olympia oyster, Ostrea lurida. Bulletin of the Bureau of Fisheries, Washington, 48(23) : 439-503.

Hopkins, A.E. 1938. Adaptation of the feeding mechanism of the oyster (Ostrea gigas) to changes in salinity. U.S Bureau of Fisheries, Bulletin No.21., vol.48 pp.345-364.

Hori, T., 1954. J. Jap. biochem.Soc., 26, 157-160.

Hori, J and D. Kasukabe, 1926. Magaki no jinkoshiiku Oyobi tennen ni okeru kaigara shichu no gaitaki ni tauite (On the Artificial Culture of Ostrea gigas and the Enemieis of oyster Larvae). Suikoshiho, 22(3),77-188.

Hornell, J. 1908. Report on the suitability of Pulicat Lake for Oyster-Culture. Madras. Fish Bull. 4 : 1-23.

Hornell, J. 1910a. Note on an attempt to ascertain the principal determining factor in oyster spawning in Madras backwaters (Madras Fish. Investigations,1908), Madras Fish. Bull., 4 : 25-31.

Hornell, J. 1910b. The practice of oyster culture at Arcachon (France) and its lessons for India. Ibid., 5: 1-90.

Hornell, J. 1914. A note on the edible oyster, Madras Fish. Bull., No.8. 1-10pp.

Hoshina, T., and Ogina, C. 1951. Studien veber Gymnophalloides tokiensis Fujita, 1925. 1. Veber die Ein urkung der larvalen Trematoda auf die chemische Komponente and das Waschstum von Ostrea gigas Thunberg. J. Tokyo Univ. Fish. 38. 350-355.

Hotchkiss, R.C. 1955. The biological role of the deoxypentose nucleic acid. Pages.435-473 in E. Chargaff and J.N. Davidson eds: The nucleic acids, Chemistry and biology. Vol. 2 Academic Press, New York.

Houteville, P., and Lubet,P. 1975. The sexuality of Pelecypod molluscs. In 'Intersexuality in the Animal Kingdom' (R. Reinboth, Ed.), pp.179-187. Springer-Verlag, Berlin and New York.

Howell, M. 1966. A contribution to the life history of Bucephalus longicornutus (Manter, 1954). Zool. Publ. Victoria Univ. New Zealand. No. 40, 42pp.

Humphrey, G. 1941. The determination of glycogen in oysters. Aust. J. Expt. Biol. med.Sci., 19, 311-341.

Hynes, H.B.N. (1950). The food of fresh water stickle-backs (Gastrosteus aculeatus and Pygosteus punigtuis) with a review of methods used in the studies of food and fishes. J. Anim. Ecol. 19 : 36-88.

Imai, I and Saki, S. 1961. Study of breeding of Japanese oyster, Crassostrea gigas. Tohoku Journal of Agricultural Research. 12(2) : 125-171.

Ingle, R.M. 1950. Summer growth of the American oyster in Florida waters. Science. 12, 338-339.

Ivantsch, G.F. 1970. The effects of high temperatures on the gonadal area of reproductive cross section of Mytilus edulis L. Masters' Thesis Universiy of Delaware, New York, Delaware, 67pp.

Jafri, A.K and S. Mustafa. 1976. Nucleic acids in the dark and white muscles of freshwater carp, Barbus stigma (Cuv. and Val.). Curr. Sci. 45 : 415-416.

Jeng, Sen-Shyong, Shun-Yao Hsu and Guoo Shyng Wang, 1979. Chemical composition of Taiwan's oysters and clams. Bull. Inst. Zool. Acad. Sin (Taipei) 18(1) 1-10. (Kaohsiung Inst, Mar. Technol., Kaolsiung,Taiwan).

Joel, D.R. 1973. Studies on the Biology and Fisheries of the edible Portunid crabs of the Pulicat Lake. Ph.D Thesis. Univ. Madras, 123 pp.

Jones, S. 1968. The molluscan fishery resources of India. Proc. Symp. Mollusca, Mar. biol. Ass. India Part III, 906-918.

Jorgensen, C. Barker, 1952. On the relation between water transport and food requirements in some marine filter feeding invertebrates. Biological Bulletin Vol. 105 No.3, pp 477-489.

Joseph, M.M. and S. Joseph, 1980. Some aspects of experimental culture of the oyster Crassostrea madrasensis(Preston) Symposium on Coastal Aquaculture, Cochin, 12-18 Jan. 1980. Mar. biol. Ass. India. Abstract. 174.

Joshi, M.C. and Bal, D.V. 1965. Observations on the chemical composition of the clam, Katelysia mormorata. J. Zool. Soc. India, 17. 108-113.

Kaliyamurthy,M. 1973. Observations on the transparency of the waters of the Pulicat Lake with particular reference to plankton production. Hydrobiologia,41(1):3-11.

Katkansky, S.C and Sparks, A.K. 1966. Seasonal sexual patterns in the Pacific oyster, Crassostrea gigas in Washington State. Washington Department of Fisheries, Fisheries Research Papers, 2(4) : 80-89.

Kennedy, A.U. and Battle, H.I. 1964. Cyclic changes in the gonad of the American oyster, C. virginica (Gmelin) Can. J. Zoology, 42(2) : 305-321.

Kinne,O. 1963. The effect of temperature and salinity on marine and brackishwater animals. Oceanogr. Mar. Biol. 1, 301-340.

Kinne,O. 1964. The effects of temperature and salinity on marine and brackish water animals. Oceanogr. Mar. Biol. 2, 281-339.

Kinne, O. 1970. Temperature, animals, invertebrates. In: 'Marine Ecology, A Comparative Treatise on Life in Oceans and Coastal waters' (O. Kinne, ed) Vol.I, Part L, pp. 407-514. Wiley(Interscience), New York.

Kirby-Smith, W.W. 1970. Growth of the Scallops, Argopecten irradians concentricus (Say) and Argopecten gibbus (Linne) as influenced by food and temperature. Ph.D Thesis, Duke Univ. Durban, North Carolina.

Kirch-choff, C. 1981. Electrophoretic analysis of Newly synthesized and stored maternal RNA during oogenesis of Calliphore erythrocephala.

Knight-Jones, E. W. 1952. Reproduction of oysters in the rivers Crouch and Roach, Essex, during 1947, 1948 and 1949. Fishery Invest. Lond. 18, 1-48.

Korringa, P. 1941. Experiments and observations on spawning pelagic life and setting in the European flat oyster, Ostrea edulis L. Arch. neerl. Zool. 5: 1-249.

Korringa, P. 1952. Recent advances in Marine Biology. Quaterly Rev. Biol. 30 : 393-429.

Korringa, P 1976. Development in Aquaculture and Fisheries Volume I : Farming marine organisms low in the food chain 262pp. Vol.II Farming the cupped oysters of the Genus Crassostrea. 224pp. Vol.III. Farming the flat oyster of the Genus Ostrea 238pp. Elsevier Scientific publishing Co., Amsterdam, Oxford, New York.

Krishnamurthy, K. 1967. Seasonal variations in the plankton of Porto Novo waters (India). Hydrobiologia, 29:226-38.

Krishnamurthy, K.N. 1971. Preliminary studies on the bottom biota of Pulicat lake. J. mar. biol. Ass. India, 13 1 & 2 : 264-269.

Krishnakumari,L., Rajagopal,M.D and Sumitra Vijayaraghavan,1977. Some aspects of biology and biochemistry of the back-water clam Meretrix casta (Cheminitz), Mahasagar Bull. Nat. Inst. Oceanogr., 10(3/4) : 157-163.

Krishnamurthy, R.V., G.I.Lakshmi, Petricia Biesiot and A. Venkataramiah. 1979.
Variations in glycogen, total fat and caloric energies of the American oyster Crassostrea virginica from from the natural reefs in the Mississippi Sound, USA. Indian Acad. Sci. Sect. B 88(6 pat I) 397-410.

Lane, C.E. Posner,G.S, and Greenfield,L.J. 1952. The distribution of glycogen in the shipworm, Teredo (Lyrodus) pedicellata. Quatrefages Bull. Mar. Sci. Gulf Caribb. 2, 385-392.

Lawrence, J.M. and Giese,A.C. 1969. Changes in the lipid composition of the chiton, Katherina tunicata with the reproduction and nutritional state. Physiol. Zool., 4 : 353-360.

*Le Dante, J. 1968. Ecologie et reproduction de l'huitre portuguise (Crassostrea angulata Lamarck) dan le bassin d' Arcachon et sur la rive ganche derla Gironde; second partie. Revue des Travanx Institut de peches Maritimes 32(3) : 301-59.

Lee, C.F. and Pepper,L. 1956. Comml. Fish. Rev., 18: 1-6.

Leslie, I. 1955. The nucleic acid content of tissues and cells pages 1-50 in E. Chargaff and J.N. Davidson, eds. The nucleic acids, Chemistry and biology, Vol.2. Academic Press. New York.

Little, J.W., Hopkins,S.H. and Schlict, F.G. 1966. Acanthoparyphium spinulosum (Trematode : Echinostomatidae) in oysters at Port Isabel, Texas. J. Parasitol. 52, 663.

Lomte,V.S and Nagabhushanam,R. 1969. Reproductive cycle in the freshwater mussel. Parreysia corrugata. Marath. Univ. J. Sci. 8 : 113-118.

Loosanoff, V.L. 1937a. Development of the primary gonad and sexual phases in Venus mercenaria Linnaeus. Biol.Bull., Woods Hole 72 : 389-405.

Loosanoff, V.L. 1937b. Seasonal gonadal changes of adult clams Venus mercenaria (L). Ibid. 72 : 406-416.

Loosanoff, V.L. 1937c. Spawning of Venus mercenaria (L) Ecology, 18 : 506-575.

Loosanoff, V.L. 1942. Seasonal gonadal changes in the adult oysters, Ostrea virginica of Long Island Sound. Biol. Bull., Woods Hole 82 : 195-206.

Loosanoff, V.L. 1948. Gonad development and spawning of oysters (O. virginica) in low salinities. Anat.Rec., Vol. 101, No.4, p.55.

Loosanoff, V.L. 1949. On the food selectivity of oysters. Science, Vol. 110, No. 2848. p.122.

Loosanoff, V.L. 1953. Reproductive cycle in Cyprina islandica Biol. Bull. (Woods Hole, Mass.) 104, 146-155.

Loosanoff, V.L. 1965a. Gonad development and discharge of spawn in oysters of Long Island Sound. Biol. Bull. (Woods Hole, Mass.) 129, 546-561.

Loosanoff, V.L. 1969. Maturation of gonads of oysters, Crassostrea virginica of different geographical areas subjected to relatively low temperatures. Veliger II, 153-163.

Loosanoff, V.L. 1971.. Development of shellfish culture techniques. Proc. Conf. Artif. Propag. Commer.valuable shellfish. Oysters, Coll, Mar. Stud., Univ. Delaware pp.9-40.

Loosanoff, V.L and Davis. H.C. 1952. Temperature requirements for maturation of gonads of norther oysters. Biol. Bull. (Woods Hole, Mass.) 103, 80-96.

Loosanoff,V.L and Engle, J.B. 1940. Spawning and setting of oysters in Long Island Sound in 1937, and discussion of the methods for predicting the intensity and time of oyster setting. U.S. Bur. Fish. Bull. 49, 217-255.

Loosanoff, V.L. and Nomejko, C.A. 1951a. Existence of physiologically differenc races of oysters, Crassostrea virginica. Biol. Bull. (Woods Hole, Mass) 101, 151-56.

Loosanoff, V.L. and Nomejko, C.A. 1951b. Spawning and setting of the American oyster, O. virginica in relation to lunar phases. Ecology 32, 113-134.

Lopez-Benito, M. 1955. Investigason pesq., 1, 137-51.

Lotsy, J.P. 1893. U.S. Fish. comm., 1893.

Love, R.M. 1958. Studies on the north sea cod. II. Deoxyribo-nucleic acid in the musculature. J. Sci. Food Agric. 9 : 199-203.

Mackin, J.G. 1951. Histopathology of infection of Crassostrea virginica (Gmelin) by Dermocystidium marinum Mackin, Own, and Collier. Bull. Mar. Sci., Gulf Caribbean 1, 72-87.

Mackin, J.G. 1961. Mortalities of oysters, Proc. Nat. Shellfish. Assoc. 51 : 21-40.

Mackin, J.G. 1962. Oyster disease caused by Dermocystidium marinum and other microorganisms in Lousiana. Publ. Inst. Marine Sci. 7. 132-229.

Mahadevan, S. 1980. Fishery and Biology of edible oysters.

Proceedings of the Summer Institute in Culture of edible molluscs held at Tuticorin Res. Centre of CMFRI, from 26 May- 24 June '80, 1-169pp.

Malcolm, W.B. 1971. The Sydney rock oysters. Aust. Nat. Hist., 17(2) : 46-50.

Mane, U.H. 1973. Study on the biology of marine clam, Katelysia opima. Ph.D. Thesis, Marathwada University, Aurangabad.

Mane, U.H. and Nagabhushanam. R. 1975. Body distribution and seasonal changes in the biochemical composition of the estuarine mussel, Mytilus viridis at Ratnagiri. Revista biol. 163-174.

Mane, U.H. and Nagabhushanam, R. 1976. A study on the reproductive biology of Indian oyster, Crassostrea gryphoides. Nat. Sci. J. Marath. Univ. Aurangabad, Vol. XV Sci. 8 : 245-258.

Maskert, C.L and I.Faulhaber, 1965. Lactate dihydrogenase isozyme patterns of fish. J. Exp. Zool. 159: 319-332.

Mason, J. 1958. The breeding of the scallop, Pecten maximus in Manx water. J. Mar. Biol. Assoc. U.K. 37,653-71.

Masumoto, B., Masumoto, M and Hibino, M. 1934. Biochemical studies of Magaki (Ostrea gigas). II. The seasonal variation in the chemical composition of Ostrea gigas. J. Sci. Hiroshima Univ. A4 : 47-56.

Medcof, J.C. 1955. Day and night characteristics of spatfall and of behaviour of oyster larvae. J. Fish. Res. Board Can. 12, 270-286.

Menzel, R.W and Hopkins, S.H. 1955. The growth of oysters parasitized by the fungus Dermocystidium marinum and by the Trematode, Bucephalus cuculus. J. Parasitol. 41. 333-342.

Mercy Bai, P. 1980. A comparative study on the Reproductive biology of two estuarine polychaetes, Marphysa gravelyi and Lycastis indica. Ph.D. Thesis, Univ. of Madras.

Mermod, J.J; Jacobs Lorena, M; Crippa, M. 1977. Change in rate of RNA synthesis and Ribosomal Gene Number during oogenesis of Drosophila melanogaster, Dev. Biol. 57: 393-402.

Millar, R.H. 1963. Oysters killed by Trematode parasites. Nature, Vol. 197, No. 4867. p 616 only.

Millar, R.H. 1964. Breeding and gonadial cycle of oysters in Loch Ryan. Scotland. J. Cons. Cons. Perm. Int. Explor. Mar. 28, 432-439.

Millar, J.M. and Epel. D. 1973. Studies of oogenesis in Urechis caupo, II. Accumulation during oogenesis of carbohydrates, RNA, microtubule protein, and soluble mitochondrial and lysosomal enzymes. Dev. Biol. 32: 331-344.

Milroy, J.A. 1907. Scient. Invest. Fish. Brch. Ire., 1907(1) 1-5.

Mirsky, A.E., and H. Ris. 1951. The deoxyribonucleic acid content of animal cells and its evolutionary significance. J. Gen. Physiol. 34: 451-462.

Mitchell,P.H., 1916. Bull. U.S. Bur. Fish. 35, p.477.

Miyazaki, I. 1938. On fouling organisms in the oyster farm. Bull. Jap. Soc. Scient. Fish, 6: 223-32.

Morals, M.A., Jabbagy, A.J. and Terenzi, H.P. 1973. Neurospora Newsletter, 20-24.

Moses, S.T. 1928. A preliminary report on the anatomy and life history of the common edible backwater oyster, Ostrea madrasensis. J. Bombay nat. Hist. Soc., 32 : 548-553.

Mustafa, S. 1977. Nucleic acid turnover in the dark and white muscles of some freshwater species of carps during growth in the pre-maturity phase. Copeia. 1977: 173-176.

Nagabhushanam, R. 1961. Biochemical studies on the marine wood-boring mollusc Martesia striata. Jour. Scient. Ind. Res., 20c, 171-173.

Nagabhushanam, R and D.S. Bidakar, 1975. Adaptations to the common rock oyster Crassostrea cucullata to low salinit es at Ratnagiri. Bull. Dept. Mar. Sci. Univ. Cochin, 1975, VII, 2, 409-417.

Nagabhushanam, R and K.P. Dhamne, K.P. 1977a. Seasonal variations in Biochemical constituents of the clam, Paphia laterisulca, Hydrobiologia vol. 54, 3: 209-214.

Nagabhushanam,R and Dhamne, k.P. 1977b. Seasonal gonadal changes in the clam, Paphia laterisulca. Aquaculture, 10: 141-152.

Nagabhushanam, R and Dheshmukh. R.S. 1974. Seasonal changes in the body component indices and chemical compostion in the estuarine clam, Meretrix meretrix. Indian J. Fish. 21(2) : 531-542.

Nagabhushanam, R and V.S. Lomte, 1977. Biochemical composition of different body components of the freshwater mussel, Parreysia corrugata. Marathwada Univ. J. Sci., Vol. XI. 299-303.

Nagabhushanam, R and Mane, U.H. 1973. Marathwada Univ. J. Sci. 12 (5) : 193-203.

Nagabhushanam, R and Mane, U.H. 1975. IIIrd All India Symp. on Est. Biol. Cochin, India.

Nagabhushanam, R and B.M. Mantale, 1972. Studies on the biochemical composition of the oyster Crassostrea gryphoides. Marathwada Univ. J. Sci., 11(4) : 47-53.

Nagabhushanam, R and P.M. Talikhedkar. 1977. Seasonal variation in protein, fat and glycogen of the wedge clam Donax cuneatus. Indian J. Mar. Sci. Vol. 6, No.1 : 215-217.

Naidu, K.S. 1970. Reproduction and breeding cycle of giant scallop, Placopecten magellanicus in Portan Port Bay. Newfoundland, Can. J. Zool., 48: 1003-1012.

Nayar,K. Nagappan. 1955. Studies on the growth of the wedge clam, Donax(Latone) cuneatus Linnaeus. Indian J. Fish., 2 : 325-348.

Natarajan, A.V. and Jhingran, V.G. 1961. Index of preponderance- A method of grading the food elements in the stomach analysis of fishes. Indian. J. Fish. 8: 54-59.

Needler, A.B. 1932. Sex reversal in Ostrea virginica. Contributions to Canadian Biology and Fisheries 7: 285-294.

Needler, A.B. 1942. Sex reversal in individual oysters. Jour. Fish. Res. Bd. Can. 5(4) : 361-364.

Nelson, T.C. 1928a. Relation of spawning of the oysters to temperature. Ecology, 9, 145-154.

Nelson, T.C. 1928b. On the contribution of critical temperatures for spawning and for ciliary activity in bivalve molluscs. Science, 67, 220-221.

Nelson, T.C. 1942. The oysters. The Boylston Strait Fishweir. Pap. Peabody Fdn. Archeol., 2, 49-64.

Numachi, K., Oizumi,J., Sato, I., and I. Imai. 1965. Studies on the mass mortality of the oysters of Matsushima Bay. III. The pathological degenerations of oysters by Gram-positive bacteria and their frequency. Tohoku Reg. Fisheries Res.Lab. Rept. 25, 39-47.

Ockelmann, K.W. 1968. The zoology of East Greenland marine lamellibranchiata. Medd. Groenl. 122, 1-256.

Ogaswara. Y., Kobayashi, U., Okamoto,R., Furukawa, A., Hisooka, M., and Nogami, K, 1962. The use of suppressed oyster seed spats in the oyster culture and its productive significance. Naikai Reg. Fisheries Res. Lab. Res. Rept. 19. 1-153.

Ohno, S., V.Wolf, and N.B. Atkin. 1966. Comparative DNA values and chromosome complements of eight species of fishes. Chromosome 18 : 455-466.

Okazaki, K and Kobayashi, S. 1929. The seasonal variation of the glycogen content in the oyster Ostrea circumpicta. Sci. Rept. Tohoku Univ., 4th Ser. 4: 183-191.

Oldfield, E. 1961. The functional morphology of Kellia suborbicularis, Montacuta ferruginosa and M. substrata. Proc. Malac. Soc. London, 34, 255-295.

Orton, J.H. 1928. Sea temperature, breeding and spawning in marine animals. J. Mar. Biol. Assoc. U.K. 12: 339-336.

Orton, J.H. 1922. The phenomenon and condition of sex change in the oyster (Ostrea edulis) and Crepidula. Nature, Lond., 110-213.

Orton, J.H. 1924. Sex change and breeding in the native oyster. O. edulis. Nature, 114, 191-192.

Orton, J.H. 1926. On lunar periodicity in spawning of normally grown Falmouth oysters (O. edulis) in 1925, with a comparison of the spawning capacity of normally grown and dumpy oyster. J.Mar. Biol. Assoc. U.K. 14, 199-225.

Orton, J.H. 1927. A note on the physiology of oyster and sex determination. J. Mar. Biol. Assoc. U.K. 24. 1047-1055.

Orton, J.H. 1933. Observation and experiments on sex-change in the European oyster (O. edulis). Part III. On the fat of unspawned ova. Part IV. On the change from male to female. J. Mar. Biol. Assoc. U.K. 19: 1-5, 5-33.

Orton, J.H. 1937. Oyster biology and oyster culture, London, E. Arnold and Co. 211 pp.

Panikkar, N.K and R. Gopala Aiyyar, 1939. Observations on breeding in Brackishwater animals in Madras. Proc. Indian Acad. Sci., 98 : 343-360.

Paul, M.D. 1942. Studies on the growth and breeding of certain sedentary organisms in the Madras harbour. Proc. Indian Acad. Sci. 1158. 1-42.

Paul Raj, R.-1976. Studies on the Penaeid Prawns of Pulicat Lake, South India, Ph.D. Thesis, Univ. of Madras.

Pease, H.F. 1932. The oyster : Modern Science comes to the support of an ancient food. J. Chem. Edu., 9, 1673.

Pelseneer, P. 1906. Mollusca, In Lankester's Treatise on Zoology, Adam & Charles, Black. London. 355pp.

Pjitzenmeyer, H.T. 1965. Annual cycle of gametogenesis in the soft shelled clam Mya arenaria at Solomon, Maryland, Chesapeake. Sci. 6, 52-59.

Pollack, S. B, and Telfer, W.H. 1969. RNA in Ceoropia moth ovaries. Sites of synthesis. Transport, and storage. J. Exp. Zool : 1-24.

Pomerat,C.M., and Reiner, E.R. 1942. The influence of surface angle and of light on the attachment of barnackes and other sedentary organisms. Biol.Bull. Mar. Biol. Lab., Woods Hole, 82 : 14-15.

Prashad, R.R. 1956, The characteristics of the marine plankton at an inshore station in the Gulf of Mannar, near Mandapam. Indian J. Fish., 1(182) : 1-36.

Pritchard, Donald. W. 1952. A review of our present knowledge of the dynamics and flushing of estuaries. Chesapeake Bay Institute of the Johns Hopkins Univ., Technical Report 4, References 52-57, 45pp.

Prytherch, H.F. 1928. Investigations of the physical condition controlling spawning of oysters and the occurrence, distribution and setting of oyster larvae in Milford Harbour, Connecticut, Fish. Bull. U.S., 44: 429-503.

Purushan, K.S., U.K. Gopalan and T.S.S. Rao. 1980. Raft culture experiment on the edible oyster, Crassostrea madrasensis (Preston) in Cochin backwater. Symposium on Coastal Aquaculture, Cochin, 12-18 Ja. 1980, JMBAI, Abst. 173.

Quayle, D.B. 1943. Sex, gonad development and seasonal gonad changes in Paphia staminea Concord. J. Fish. Res. Bd. Can. 6 : 140-151.

Quayle, D.B. 1969. Pacific oyster culture in British Columbia. Bull. Fish. Res. Board. Can. 169: 1-192.

Quayle, D.B. 1971. Pacific oyster raft culture in British Columbia. Bulletin, 178. Fish. Res. Bd, Can. Queens Printer, Ottawa. pp. 34.

Quayle, D.B. 1975. Tropical oyster culture. A selected bibliography. International development Research Centre. IDRC-052e-Ottawa, pp.40. A basic list of publications on tropical oyster culture.

Quayle, D.B. 1980. Tropical oysters : culture methods. Ottawa, Ont., IDRC, 1980. 80pp.

Radhakrishnan,S. 1973. Some aspects of the distribution and seasonal abundance of macrophytic flora in lake Pulicat, India. Abst. No. 24. Regional Seminar on Noxious vegetation in Tropis and Sub-tropics heldat New Delhi during 12-17 Dec. 1973, 29-30.

Rahman, A.A. 1965. The chemical composition of the lamelli-branch Donax cuneatus Linn. Proc. Indian Acad. Sci., Sect. B 62, 188-192.

Rai, H.S. 1932. The shell fisheries of the Bombay presidency. J. Bombay nat. Hist. Soc., 35(4) : 826-847.

Raman, K., K.V. Ramakrishna , S. Radhakrishnan and G.R.M.Rao 1975. Studies on the hydrobiology and benthic ecology of lake Pulicat. Bull. Dept. Mar. Sci. Univ. Cochin, 1975. VII, 4 855- 884.

Ram mohana Rao, G. 1974. Observations on the seasonal abundance and distribution of bottom fauna in the lake Pulicat. Abst. Seminar on the development of Inland Fisheries in Tamil Nadu, Coimbatore.

Rajapandian, M.E and C. T. Rajan. 1980. Studies on the gonadal maturity and spawning periodicity of Crassostrea madrasensis (Preston) at Tuticorin bay. Symp. Coastal Aquaculture, 1980, Cochin, J. Mar. Biol.Ass. India. Abst. 60.

Rao, K. Satyanarayana. 1967. Annual reproductive cycle of the wedge clam Donax cuneatus (Linnaeus). J. Mar biol. Ass. India. 9(1) : 141-146.

Rao, K. Virabhadra, 1951a. Observations on the probable effects of salinity on the spawning, development and setting of the Indian backwater oyster, Ostrea madrasensis Preston, Proc. Indian. Acad. Sci. 33B: 231-256.

Rao, K. Virabhadra, 1951b. Studies on the growth of Katelysia opima(Gmelin). Proc. Indo-Pacific, Fish Counc., Sect. II, 94-102.

Rao, K. Virabhadra, 1953. Sex change in the oviparous Indian backwater oyster, Ostrea madrasensis Preston, Curr. Sci., 22 : 377-378.

Rao, K. Virabhadra, 1956. Seasonal gonadal changes in the oyster Ostrea (Crassostrea) madrasensis(Preston)from Ennur near Madras. Proc. Indian Acad.Sci. 44B: 332-56.

Rao, K. Virabhadra and K. Nagappan Nayar. 1956. Rate of growth in spat and yearlings of the Indian backwater oyster, Ostrea madrasensis(Preston). Ind. J. Fishe, 3:231-260.

Ray, S.M. 1954. Biological studies of Dermocystidium marinum a fungus parasite of oysters. Rice. Inst. Pam,, Spec Issue, No. 1954, Monograph. Biol. 114 pp.

Reid, R.G.B. 1969. Seasonal observations on diet and stored glycogen and lipids in the horse clam, Tresus capax (Gould,1850). Veliger, II : 378-381.

Reuben,S;T, Appa Rao and P.E.S. Manickam. 1980. Culture experiments on the edible oyster Crassostrea madrasensis in the Bhimunipatnam backwaters. Symp. Coastal Aquaculture. 1980, Cochin, J. Mar. biol. Ass. India. Abst. No. 171.

Rice, M.E. 1974. Gametogenesis in three species of Sipunculids Phascolosoma agassizii, Gelfingia pugettensis and Themiste pyroides. Le cellule, 70: 297-323.

Ropes, J.W. 1968. Reproductive cycle in the surf clam, Spisula solidissima. Proc. Natl. Shellfish. Assoc. 58, 63-65.

Ropes, J.W. and Stickney, A.P. 1965. Reproductive cycle of Mya arenaria in New England. Biol. Bull. (Woods Hole, Mass.) 135. 349-365.

* Runnstrom, S. 1927. Uber die Thermopathic der Fortpflanzung and Entwickleung mariner Tiere in Beziching zu ihrer geographischen Verbreitung. Bergens Mus. Arbok. Naturvitensk. Rekke No. 2 1-67.

* Runnstrom,S. 1936. Die Anpassung der Fortpflanzung and Entwickleung mariner Tiere an die Temperaturverhaltnisse Naturvitensk. Rekke No. 311-36.

Roughley, T.C. 1926. An investigation of the cause of an oyster mortality on the Georges River, New South Wales, 1924-25. Proc. Linnaeus Soc. N.S.Wales 51, 446-491.

Roughley, T.C. 1933. The life history of the Australian oyster, (Ostrea commercialis). Proc. Linn. Soc. N.S.W., 56 : 273-333.

* Russel. 1898. History of the Buckingham Canal Project. Madras Government Press.

Russel, E.S. 1923. Fishery Invest., Lond., Ser.2,6. No.1: 1-24.

Ruthmann, A. 1964. Zellwachatum and RNA synthesize in E l Nahrzellver von Ophryotrocha pueritis. Z. Zellforsch. Mikrask. Anat. 63, 816-819.

Sakuda, H.M. 1966. Reproductive cycle of American oyster, Crassostrea virginica in West Loch, Pearl Harbour Hawaii. Trans. Am. Fish. Soc., 95(2) : 216-218.

Saraswathy, M and Nair, N.B. 1969. Biochemical changes in relation to breeding cycles of Nausitora hedleyi Schepman (Bivalvia : Teredinidae). Curr. Sci, 38(7) 158-160.

Sastry, A.N. 1965. Reproduction of the bay scallop, Aequipecten irradians Lamarck. Influence of temperature on maturation and spawning. Biol. Bull.(Woods Hole, Mass.) 126 : 146-154.

Sastry, A.N. 1966. Temperature effects in reproduction of the bay Scallop, Aequipecten irradians Lamarck Biol. Bull. (Woods Hole, Mass.) 130 : 118-134.

Sastry, A.N. 1968. Relationship among food, temperature and development of the bay scallop, Aequipecten irradians Lamarck. Physiol. Zool. 41 : 44-53.

Sastry, A.N. 1970a. Reproductive physiological variation in latitudinally separated populations of the bay scallop, Aequipecten irradians Lamarck. Biol. Bull.(Woods Hole, Mass.) 138 : 56-65.

Sastry, A.N. 1970b. Environmental regulation or oocyte growth in the bay scallop, Aequipecten irradians Lamarck. Experimentia 26, 1371-1372.

Sastry, A.N. 1975. Physiology and Ecology of reproduction in marine invertebrates. In 'Physiological Ecology of Estuarine Organisms' (F.J. Vernberg, ed), pp. 279-29[illegible]. Univ. of South Carolina Press, Columbia.

Sastry, A.N. and Blake, N.J. 1970. Regulation of gonad development in the bay scallop, Aequipecten irradians Lamarck. Biol. Bull. (Woods Hole, Mass.) 140, 274-29[illegible].

Schaefer, M.B. 1937. Attachment of larvae of Ostrea gigas, the Japanese oyster, to plane surfaces. Ecology. 18: 523-527.

Schneider, W.C, 1957. In 'Methods in Enzymology' vol. III, pp. 680 (Ed. Colowick, S.F. and Kaplan, N.O), Academic press, New York.

Sekine,S., S. Tatshima and F. Imamura. 1929. On the seasonal variation in the chemical composition of oysters. Proc. 4th. Pac. Sci. Conq. 3 : 349-351.

Shaw, W.N. 1967. Seasonal gonadal cycle of the male soft shell clam, Mya arenaria, in Maryland. Spec. Sci.Rep. U.S. Fish. Wildl. Serv., (Fish), No. 508; 1-5.

Shaw, W.N. 1967. Seasonal fouling and oyster setting on asbestos plates in Broad Creek, Talbet country, Maryland, 1963-65. Chesapeake Sci. 8: 228-36.

Sindermann, V.J. 1966. Parasites of oyster, Crassostrea virginica, from the east coast of North America. Proc.Ist. Intern. Congr. Parasitol., Rome. 1964. Vol. II pp. 585-595.

Sindermann, C.J. 1968. Oyster mortalities, with particular reference to Chesapeake Bay and the Atlantic coast of North America. U.S. Fish Wildl. Serv., Spec. Sci. Rept., Fisheries No. 569, 1-10.

Sindermann, C.J., and Rosenfield, A. 1967. Principle disease of commercially important marine bivalve molluscs and Crustacea, U. S. Fish Wildl. Serv., Fishery Bull. 66, 335-385.

Sivankutty Nair, G. and Shynamma, G.S. 1975. Bull. depart. mar. Sci. Univ. Cochin, 7 (1975) 403.

Sparck, R. 1950. Investigations on the biology of the oyster, XII. On the fluctuations in the oyster stock of Northwestern Europe, Rept. Danish Biol. Sta., 52, 41-50.

Sprague, V. 1963. Revision of Genus Haplosporidium and restoration of Genus Minchinia (Haplosporia, Haplosporidae) J. Protozool. 10, 263-266.

Srinivasan, V.V. 1963. Curr. Sci., 32, 211-213.

Srinivasan, V.V. and Krishnaswamy, S. 1964. Zool. Jb., Physiol. 70, 539-546.

Srinivasan, A. and Pillay, K.V.N. 1972. Hydrology of Pulicat lake. Proceedings on Seminars on Mariculture and mechanised fishing held at Madras 28-29, Nov. 1972, 60-66.

Stafford, J. 1913. Commission on Conservation, Canada. Committee on fisheries, Game and Furbearing animals :159.

Stenzel, H.B. 1971. Treatise on Invertebrate Paleontology. Pt.3 Mollusca, 6. Bivalvia: N. 953-N-1224.

Stephen, D. 1977. Parasitic castration of the Indian back water oyster Crassostrea madrasensis(Preston) by the larval trematode Bucephalus sp. Sci. Cult., 43, 387-88.

Stephen, D. 1980. The reproductive biology of the Indian oyster Crassostrea madrasensis. I. Gametogenic pattern and salinity. Aquaculture 21(2): 139-146.

Stephen, D. 1980. The reproductive biology of the Indian oyster. C. madrasensis. 2. Gametogenic cycle and biochemical levels. Aquaculture 21(2) : 147-154.

Strickland, J.D.H. and T.R. Parsons. 1968. A practical handbook of seawater analysis. Bull.Fish Res.Bd. Can., 167.

Sundaram,N and K. Ramadoss, 1978. Methods of spat collection in the Culture of Shellfishes. Seafood Export Journal. Vol. X No.6, 1-6.

Sutcliffe, W.H. Jr. 1965. Growth estimates from ribonucleic acid content in some small organisms. Limnol. Oceanogr. 10 (Suppl) : R 253-R 258.

Sunder Raj, B. 1930. Administration reports; Madras Fisheries for years 1929-1930, 26-28.

Takeuchi,T., Matsubara,T., Hirokawa,Y., and Tsukiyama, A. 1955. Bacteriological study on the abnormal mortality of Hiroshima oysters (Ostrea gigas L). J. Japan Fisheries Soc., 20, 1066-1070.

Takeuchi, T., Matsubara,T., Hirokawa,Y and Tsukiyama, A. 1956. Bacteriological study on the abnormal mortality of Hiroshima oysters (Ostrea gigas). II. J. Japan Fisheries Soc., 21, 1199-1203.

Takeuchi,T., Matsubara,T., Hirokawa, Y., and Matsue,Y. 1957. Bacteriological studies on the abnormal mortality Hiroshima oysters (Ostrea gigas). III. J. Japan Fisheries Soc., 23, 19-23.

Takeuchi,T., Takemoto, Y., and Matsubara, T. 1960. Haematological study of bacteria affected oysters. Rept. Hiroshima Perfect. Fish. Expt. Sta. 22, No.1, 1-7, (Tranl. U.S. Joint Publ. Res. Serv. for Transl. Program, Bur. Comm, Fish., Milford, Conn.1965).

Tanaka, S., and Hatana, H. 1952. Studies on the seasonal changes in the chemical constituents of the pearl oyster. Publ. Sets Mar. Biol. Lab. 2, 341-355.

Tang Chungti and Xu Zhezzu. 1980. The 'Black root' disease of the razor clam in estuary of Juilong River, Fujian, China. Acta Hydrobiologica sinica vol. 7 No.2 167-169.

Tang Zhengzhang and Tang Chengti. 1980. Life histores of two species of Aspidogastrids and the phylogeny of the group, Acta Hydrobiologica sinica Vol. 7 No.2. 153-169.

Thangavelu. R and P. Muthiah. 1980. Predator problem of oyster farming at Tuticorin Bay: Destruction of oyster spat by Cymatium cingulatum. Symp. Coastal Aquaculture held, at Cochin, J. Mar. biol. Ass. India. Abst.No.176.

Thangavelu, R. and N. Sundaram. 1980. Experiments on edible oyster spat collection at Tuticorin. Symp. Coastal Aquacutlure held at Cochin, J. Mar. biol. Asso India. Abst. No. 99.

Thompson, R.J. 1977. Blood Chemistry, biochemical composition of tissue and the annual reproductive cycle in the giant scallop, Placopecten magellanicus(Gmelin) from southeast New foundland. J. Fish. Res. Board. Canada. 34, 2104-2116.

Thorson,G. 1950. Reproduction and larval ecology of marine bottom invertebrates. Biol. Rev. Cambridge. Philos. Soc., 25. 1-45.

Tranter, D.J. 1958a. Reproduction in Australian Pearl oysters (Lamellibranchia). III. Pinctada albina (Lamarck) breed. g season and sexuality. Aust. J. Mar. Freshwater Res. 9, 191-216.

Tranter, D.J. 1958b. Reproduction in Australian Pearl oysters (Lamellibranchia). I. Pinctada albina (Lamarck). Primary gonad development. Aust. J. Mar. Freshwater Res. 9, 135-143.

Tranter, D.J. 1958c. Reproduction in Australian Pearl oysters (Lamellibranchia). IV. Pinctada margaritifera(Linnaeus) Aust. J. Mar. Freshwater Res. 9, 509-525.

Tranter, D.J. 1958d. Reproduction in Australian pearl oysters (Lamellibranchia) II. Pinctada albina (Lamarck) : Gametogenesis. Aust.J. Mar. Freshwater Res. 9.144-158.

Tranter,D.J. 1959. Reproduction in Australian pearl oysters (Lamellibranchia). V. Pinctada fucata (Gould). Aust. J. Mar. Freshwater Res. 10, 45-66.

*Trevallion, A.C. 1965. A study of detritus feeding bivalve molluscs, and an investigation on detritus, 211pp. Ph.D. Thesis, University of Southampton.

Trevallion, A.C. 1971. Studies on Tellina tenuis Da Costa. III. Aspects of general biology and energy flow. J. Exp. Mar. Biol. Ecol. 7, 95-122.

Tully, J.P. 1936. J. Biol. Bd., Can., 2 : 477-484.

Tweedell, 1966. Oocyte development and incorporation of H^3-Thymidine and H^3-Uridine in Pectinaria. Biol. Bull. 131, 516 - 538.

Usuki, I and Koizumi, S. 1954. Scient, Rept. Tohoku Imp. Univ. Serv. 4, 20, 309.

Ukeles, R. 1971. Nutritional requirements in shellfish culture. Proc. Conf. Artif. Propag. Commer. Valuable Shellfish oysters. Coll. Mar. Stud., Univ. Delaware. pp. 43-64.

Ukeles, R. 1975. Views in bivalve larvae nutrition. Proc. Int. Conf. Aquaculture. Nutrition. Ist, Sea grant program, Univ. Delaware co-op, U.S. Jpn. Aquacult. Panel. 127-62.

Van Somersen, V.D and Whitehead, P.J. 1961. An investiration of the biology and culture of an East African oysters Crassostrea cucullata(Born). Fish. Publ. Lond.14: 1-36.

Venkataraman, R and Chari,T. 1951. Studies on oysters and clams, Biochemical variations. Indian.J. Med. Res.39: 533:541.

Vasu, B.S. and Giese, A.C. 1966. Variations in the body fluid nitrogenous constituents of Cryptochiton stellaris (Mollusca) in relation to nutrition and reproduction.

Comp. Biochem. Physiol. 19: 737-744.

Vernberg, F.J. 1962. Comparative physiology : Latitudinal effects on physiological properties of animals. Annu. Rev. Physiol. 25, 517-546.

Von Oertzen, J.A. 1972. Cycles and rates of reproduction of six Baltic sea valves of different Zoogeographic origin. Mar. Biol. 14: 143-149.

Walne,P. 1970. The seasonal variation of meat and glycogen content of seven population of oysters, Ostrea edulis Fish. Invest. ser. II 26: 1-35.

West, E.S and W.R. Todd. 1963. Text book of biochemistry. MacMillan Co., New York. 340pp.

Wilson, B.R. 1968. Survival and reproduction of the mussel Xenostrobus securus (Lamarck) (Mollusca, Bivalvia, Mytilidae) in Swan estuary, Western Australia, Part I. Salinity tolerance. J. Nat. Hist. 2, 307-328.

Wilson, B.R. 1969. Survival and reproduction of the mussel Xenostrobus securis (Lamarck) (Mollusca, Bivalvia, Mytilidae) in Western Australia. Part II: Reproduction, growth and longevity. J. Nat. Hist. 3 : 93-102.

Wilson,B.R., and Hodgkin, E.P. 1967. A comparative account of the reproductive cycles of five species of marine animals(Bivalvia : Mytilidae) in the vicinity of Fremantle, Western Australia. Aust. J. Mar. Freshwater Res. 18 : 175-203.

Wisely,B., Holiday,J.E, and Reid, B.L. 1979a. Experimental deepwater culture of the Sydney Rock oyster (Crassostrea commercialis = Saccostrea cucullata) I. Growth of vertical clumps of oysters('ren'). Aquaculture, 16 : 127-140.

Wisely,B., Holiday,J.E., and Reid, B.L. 1979b. Experimental deepwater culture of the Sydney rock oyster (Crassostrea commercialis = Saccostrea cucullata). II.Pantoon tray cultivation. Aquaculture, 16 : 141-146.

Wisely, B., Holliday, J.E, and Reic, B.L., 1979c. Experimental deepwater culture of the Sydney rock oyster (Crassostrea commercialis=Saccostrea cucullata). III. Raft cultivation of trayed oysters. Aquaculture, 17: 25-32.

Wolf, V., H. Ritter; B.B. Atkin, and S. Ohno. 1969. Polyploidization in the fish family Cyprinidae, order Cypriniformes. Humangenetik 7: 240-244.

Yokovlev, Yu. M. 1928. Reproductive cycle of the Pacific oyster in the sea of Japan.

Yonge, C.M. 1960. Oysters. Collins, London, Glascow. pp.209.

Yokota, T. 1936. Attachment of larvae of the Japanese oyster, Ostrea gigas. Rep. Fish. Expt. Stn, Miyagi Perfecture. 6 : 11.

Young, R.T. 1942. Spawning season of the Californian mussel Mytilus californianus. Ecology, 23, 490-492.

Young, R.T. 1946. Stimulation of spawning in the mussel Mytilus californianus. Ecology, 26, 58-69.

Yamaguti, S. 1958. Systema Helminthum. Vol. I. The Digenetic Trematodes of vertebrates. Interscience Publishers INC., New York. Part II.

Zolakar, M. 1976. Autoradiographic study of protein and RNA formation during early development of Drosophila eggs. Dev. Biol. 49: 425-437.

Zumoff, C.H. 1973. The reproductive cycle of Sphaerium simile, Biol. Bull., 144 : 212-228.

* Not referred in original.